AN ATLAS OF THE ANATOMY OF THE EAR

With Accompanying Color Slides

Branislav Vidić, S.D.
Saint Louis University

Ronan O'Rahilly, M.D.
Wayne State University

1971 — W. B. SAUNDERS COMPANY — Philadelphia — London — Toronto

W. B. Saunders Company: West Washington Square
Philadelphia, Pa. 19105

12 Dyott Street
London, WC1A 1DB

1835 Yonge Street
Toronto 7, Canada

Cover illustration Lateral view of the membranous labyrinth of a human embryo of eight postovulatory weeks (30 mm C.R.), showing the endolymphatic sac and duct, the three semicircular ducts (including their ampullae and the crus commune), the utricle, the saccule, the ductus reuniens, and the cochlear duct. Enlarged about 25 times. Based on a reconstruction by Streeter (Am. J. Anat., 6:139–165, 1906).

An Atlas of the Anatomy of the Ear SBN 0-7216-9015-7

 Press of W. B. Saunders Company. Library of Congress Catalog card number 70-151688.

Print No.: 9 8 7 6 5 4 3 2 1

PREFACE

It is a curious fact that very few books have been devoted to the structure of that complicated organ known as the ear, in striking contrast to the many lavishly illustrated treatises on that complicated organ known as the eye. The present volume comprises an atlas of drawings designed to complement a series of photographs, in the form of color slides, illustrating the general structure and relationships of the human ear.

Now that 35 mm slides have achieved international acceptance as a medium of visual presentation, it seems opportune to launch an anatomical atlas that is designed around that medium and which may be of interest to both medical and postgraduate students of human structure.

Each of the drawings is based on a corresponding color slide and is accompanied by a brief description. The terminology used is that of the *Nomina anatomica* of 1955, as amended in 1965, and translated into English where appropriate. Many of the descriptions are followed by one or more references that indicate where further detail may be found. The abbreviations used for journals are based on the *World List of Scientific Periodicals*, 4th edition, 1963.

Although a number of the views belong in reality to the left side of the body, they have been reversed photographically in order that all views may appear to belong to one (the right) side, thereby facilitating comparisons between one illustration and another. To appreciate how any field would appear on the left side of the body, however, it is necessary merely to view or project the slide from the opposite side.

For the attractive drawings, so carefully based on the photographs, the authors are grateful to Mr. Bill J. Briggs, M.M.A., Division of Medical Illustration, Saint Louis University, and to his collaborators: D. R. Dellucci, D. E. Diggerstaff, D. T. Magieson, and A. Porter. The authors are indebted also to Dr. George T. Nager, Division of Otolaryngology, the Johns Hopkins Hospital, for the photomicrographs of the human ear (Figures 45 to 50); to Dr. Paul H. Holinger, Department of Otolaryngology, University of Illinois, for the view of the tympanic membrane *in vivo* (Figure 21); and to Dr. James D. Ebert, Department of Embryology, Carnegie Institution of Washington, for the use of the developmental model (Figure 36). Finally, it is a pleasure to thank Mr. John L. Dusseau and the members of the staff of the W. B. Saunders Company for their unfailing assistance.

BRANISLAV VIDIĆ, S.D.

RONAN O'RAHILLY, M.D.

GENERAL REFERENCES

The following important books are devoted specifically to the structure of the ear and the temporal bone:

Anson, B. J., and Donaldson, J. A. *The Surgical Anatomy of the Temporal Bone and Ear.* Saunders, Philadelphia, 1967. This book, designed for postgraduate training in otology, consists largely of a series of 95 detailed illustrations and photomicrographs of the ear, together with their descriptions. A list of 81 references, with titles, is appended.

Bast, T. H., and Anson, B. J. *The Temporal Bone and the Ear.* Thomas, Springfield, Ill., 1949. The internal ear and the middle ear are described on a developmental basis. Included are functional and pathological considerations, and a historical survey of the internal ear. References, with titles, are listed at the end of each of the nine chapters, and an index of authors is appended.

Wolff, D., Bellucci, R. J., and Eggston, A. A. *Microscopic Anatomy of the Temporal Bone.* Williams and Wilkins, Baltimore, 1957. This is a black-and-white photographic atlas of 199 serial sections of temporal bones in three series, cut in horizontal and two vertical planes, respectively. A new edition is due to appear in 1971.

CONTENTS

Figure 31
SEMICANALS FOR TENSOR TYMPANI AND AUDITORY TUBE

Figure 32
FENESTRA COCHLEAE AND FENESTRA VESTIBULI

Figure 33
PROMONTORY AND OSSEOUS PART OF AUDITORY TUBE

Figure 34
FACIAL NERVE IN FACIAL CANAL

Figure 35
BASAL TURN OF COCHLEA

Figure 36
MODEL OF FETAL MEMBRANOUS LABYRINTH

Figure 37
POSTEROLATERAL VIEW OF OSSEOUS LABYRINTH

Figure 38
SUPERIOR VIEW OF SEMICIRCULAR CANALS

Figure 39
SUPERIOR VIEW OF COCHLEA

Figure 40
SUPERIOR VIEW OF SEMICIRCULAR CANALS AND COCHLEA

Figure 41
SUPERIOR VIEW OF SEMICIRCULAR CANALS AND MODIOLUS

Figure 42
SUPERIOR VIEW OF TENSOR TYMPANI

Figure 43
SUPERIOR VIEW OF CHORDA TYMPANI AND INCUDOMALLEAR JOINT

Figure 44
SUPERIOR VIEW OF OSSEOUS LABYRINTH

Figure 45
VERTICAL SECTION THROUGH TYMPANIC MEMBRANE, AUDITORY OSSICLES, AND EPITYMPANIC RECESS

Figure 46
VERTICAL SECTION THROUGH COCHLEA AND INTERNAL ACOUSTIC MEATUS

Figure 47
HORIZONTAL SECTION SHOWING TENSOR TYMPANI

AN ATLAS OF THE ANATOMY OF THE EAR

Figure 1. LATERAL SURFACE OF AURICLE *IN VIVO*

The auricle, together with the external acoustic meatus, constitutes the external ear. The auricle, shown here in a two-year-old child, presents a number of depressions, the largest and deepest of which is termed the concha. It leads into the external acoustic meatus. In front of the concha, a prominence, the tragus, projects backward over the meatus. A less marked elevation, the antitragus, lies behind the tragus and is separated from it by the intertragic notch.

The margin of the auricle is known as the helix. It largely surrounds another curved ridge, the anthelix, which divides above to enclose the triangular fossa. A groove known as the scapha is found between the helix and the anthelix. The lobule, which is devoid of cartilage, consists of fibrous tissue and fat. Many other variable details characterize the external morphology of each individual auricle. The names of additional eminences, notches, and grooves may be found in the *Nomina anatomica.*

The auricle develops in a complicated and disputed manner from a continuous primordium around the first pharyngeal cleft. Anomalies of the auricle are not infrequent, and sinuses and fistulae of possible developmental significance are occasionally found in or near the auricle.

REFERENCES

Adamson, G. E., Horton, C. E., and Crawford, H. H. The growth pattern of the external ear. Plast. reconstr. Surg., *36:*466–470, 1965.

Altmann, F. Malformations of the auricle and the external auditory meatus. A critical review. Archs Otolar., *54:*115–139, 1951.

Hajniš, K. Die Veränderungen der Ohrmuscheln beim Erwachsenen. Z. Morph. Anthrop., *61:*42–56, 1969.

Nomina anatomica. Excerpta Medica Foundation, Amsterdam, 3rd ed., 1968.

Perry, E. T. *The Human Ear Canal.* Thomas, Springfield, Ill., 1957.

Wodak, E. Über die Stellung und Form der menschlichen Ohrmuschel. Arch. klin. exp. Ohr.-, Nas.- u. KehlkHeilk., *188:*331–335, 1967.

FIGURE 1.

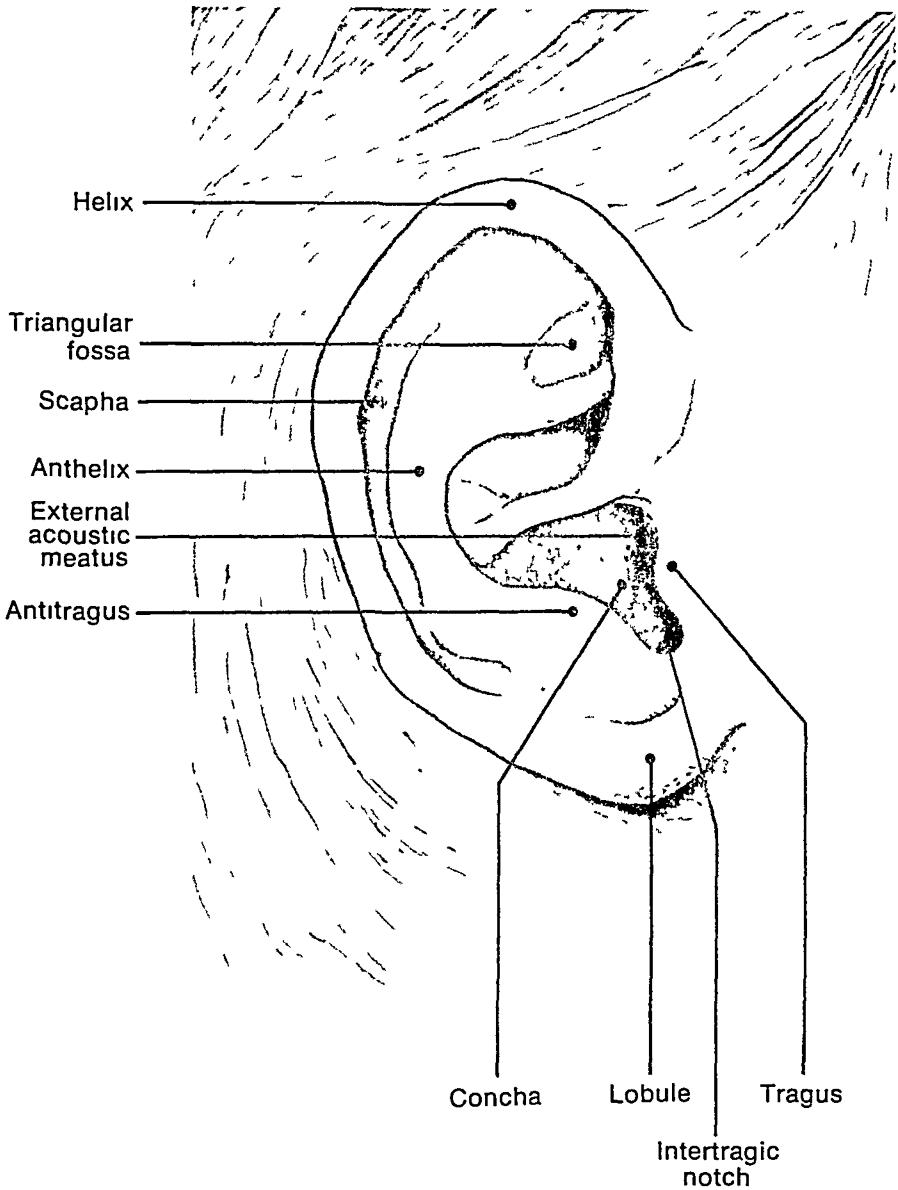


Figure 1.

Figure 2. LATERAL SURFACE OF CARTILAGE OF AURICLE *IN SITU*

The cartilage has been exposed by careful removal of the skin and perichondrium. Because the form of the auricle depends largely on that of the underlying cartilage, the latter displays most of the same features: concha, tragus, antitragus, helix, anthelix, triangular fossa, and scapha. The cartilaginous basis of the concha and tragus continues medially and becomes attached to the bony margin of the external acoustic meatus. In contrast to the intact auricle, the lower part of the cartilage displays several deep notches, *e.g.*, along the scapha (between the lowermost parts of the helix and anthelix) and between the tragus in front and the concha and antitragus behind. These notches render the cartilage less subject to damage from movement, compression, or tension.

The cartilage of the auricle presents, as a whole, many small foramina which transmit blood vessels and nerves from one surface of the auricle to the other.

FIGURE 2.

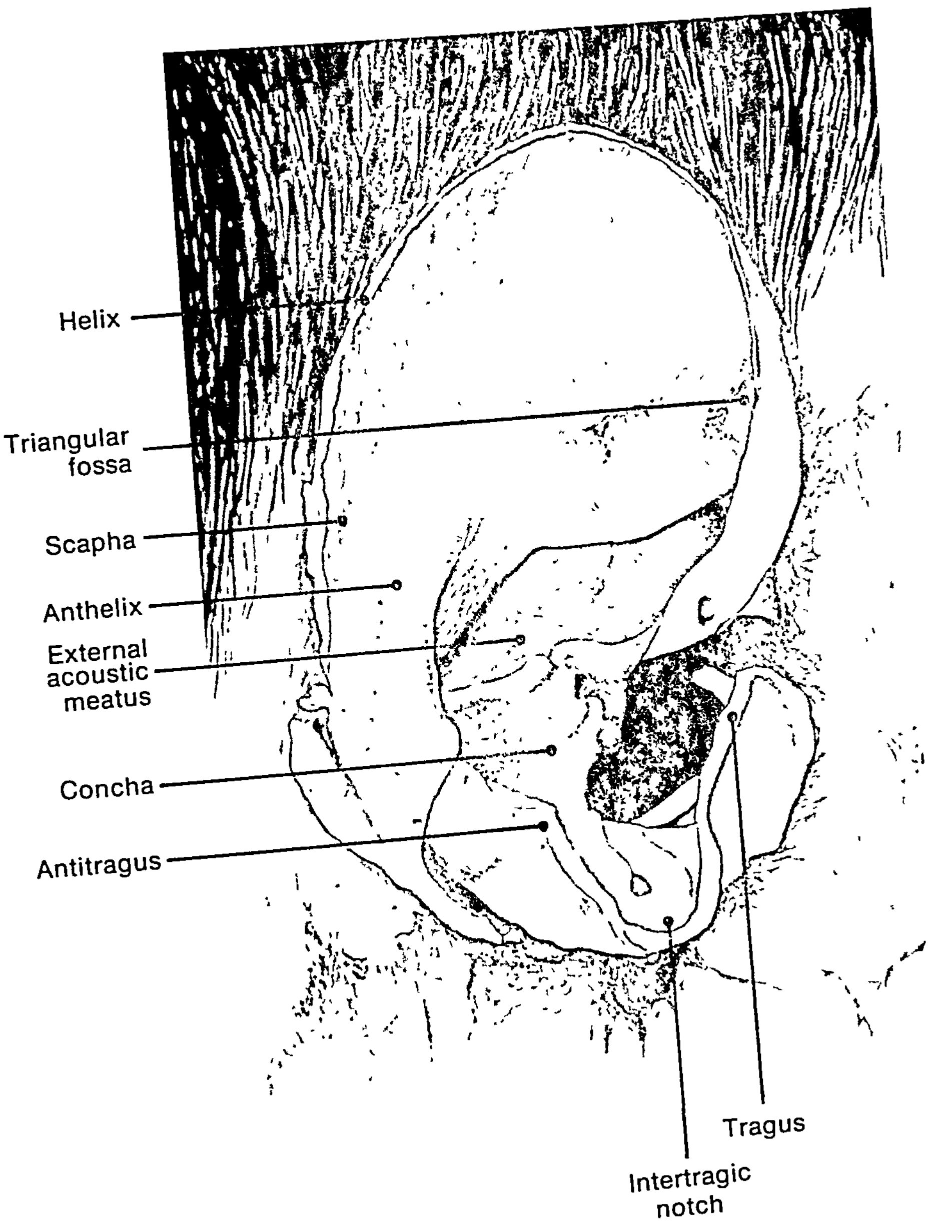


Figure 2.

Figure 3. LATERAL SURFACE OF ISOLATED CARTILAGE OF AURICLE

The various features mentioned in Figure 2 can be appreciated more clearly in this example of a cartilage from which the skin and perichondrium have been removed from both surfaces. Moreover, some of the neurovascular foramina are demonstrated to better advantage. Most of these openings are situated within depressed areas such as the concha, the scapha, and the triangular fossa; additional, smaller openings are present throughout.

With the exception of the margin of the auricle posterosuperiorly and the floor of the scapha (which is interrupted by a large number of small openings), the lateral surface of the cartilage of the auricle is smooth.

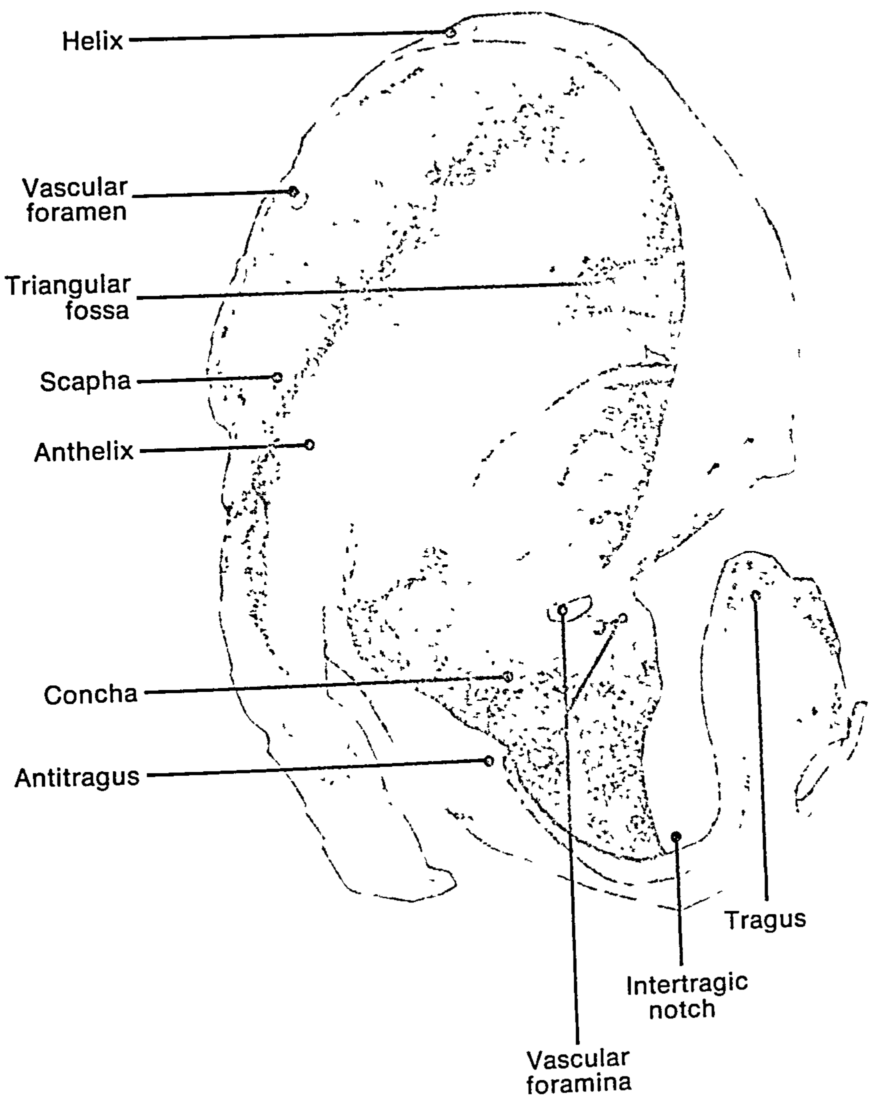

Helix
Vascular foramen
Triangular fossa
Scapha
Anthelix
Concha
Antitragus
Tragus
Intertragic notch
Vascular foramina

Figure 3.

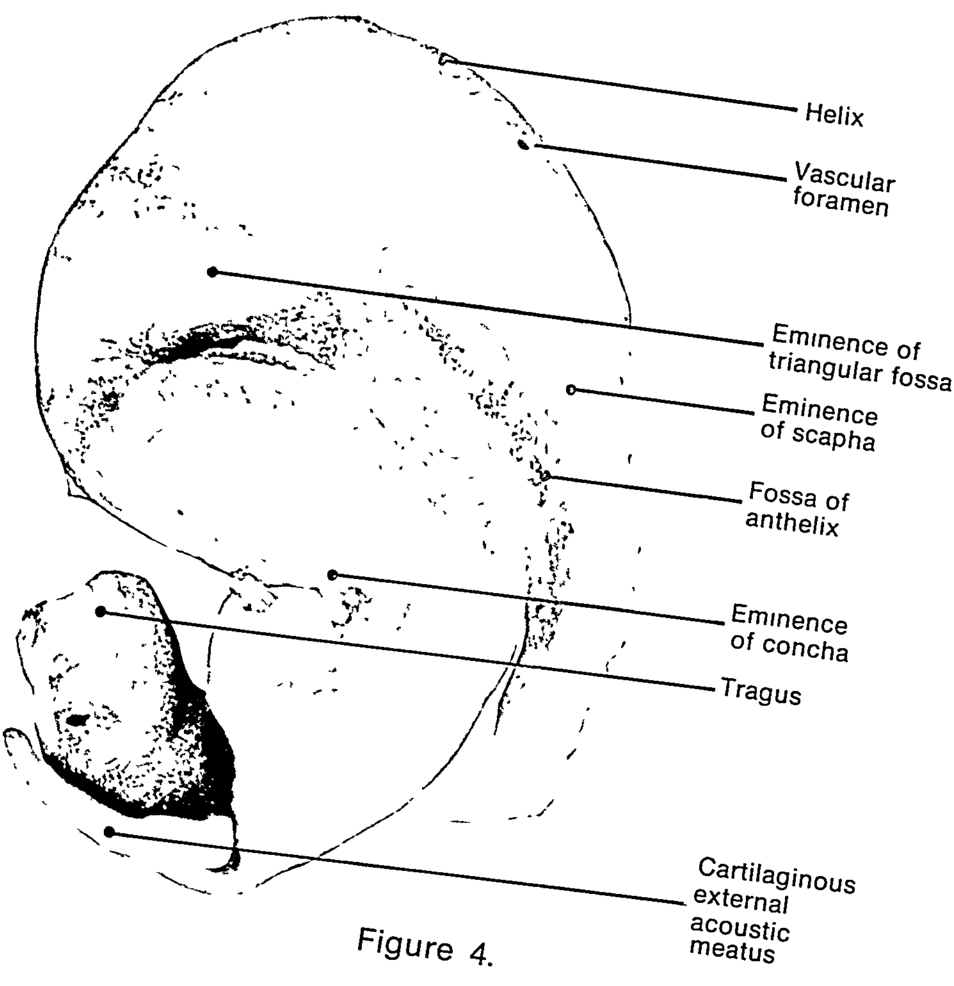
Figure 4. MEDIAL SURFACE OF ISOLATED CARTILAGE OF AURICLE

Due to the relatively uniform thickness of the cartilage, the relief of the medial surface is the reverse of that of the lateral surface. Thus the concha, the triangular fossa, and the scapha are each represented here by an eminence, whereas the anthelix now appears as a fossa. In some parts of the anthelix and the concha, the medial surface of the cartilage is irregular and rough. These irregularities correspond mainly to muscular attachments, particularly to those of the extrinsic muscles of the auricle.

The medial continuation of the concha and tragus, by which the entire cartilage is anchored to the skull, is also brought into view. This continuation constitutes the cartilaginous external acoustic meatus.

REFERENCE

Winckler, G. Remarques sur les muscles intrinsèques du pavillon de l'oreille chez l'homme. Archs Anat. Histol. Embryol., *43*:237–248, 1960.



Helix
Vascular foramen
Eminence of triangular fossa
Eminence of scapha
Fossa of anthelix
Eminence of concha
Tragus
Cartilaginous external acoustic meatus

Figure 4.

Figure 5. PERI-AURICULAR REGION (A)

Because of the important topographical relations between the auricle and the surrounding area, several views of the peri-auricular region will be presented before exposing the deeper portions of the auditory apparatus.

Immediately in front of the tragus, the superficial temporal artery, one of the terminal branches of the external carotid, emerges from the parotid gland and continues superiorly through the temporal region. In this region, the artery bifurcates into frontal and parietal branches which supply corresponding areas of the scalp. The superficial temporal vein generally follows the course of the artery. The auriculotemporal nerve also leaves the parotid gland and passes in front of the tragus before being distributed to the scalp. These three elements (artery, vein, and nerve) are all closely related to the tragus.

The lower part of the medial aspect of the auricle is approached by a subcutaneous nerve, the great auricular. Derived from the cervical plexus, this nerve carries sensory fibers from cervical nerves 2 and 3 to the skin of the auricle.

The conchal part of the auricle is related posteriorly to the mastoid insertion of the sternocleidomastoid (or, more simply, the sternomastoid) muscle.

Within the subcutaneous tissue, usually only two muscles of facial expression (risorius and platysma) overlie the parotid fascia. In exceptional cases, anomalous muscular slips may also be related to the fascia. After removal of the parotid fascia, the close relationship between the upper part of the gland and the anterior and inferior aspects of the auricle becomes evident. Among the superficial lobules of the gland, occasional parotid lymph nodes may be found. Further anteriorly, between the masseteric fascia and the anterior margin of the parotid gland, numerous terminal branches of the facial nerve emerge from under cover of the gland and radiate toward the various areas of the face.

FIGURE 5.

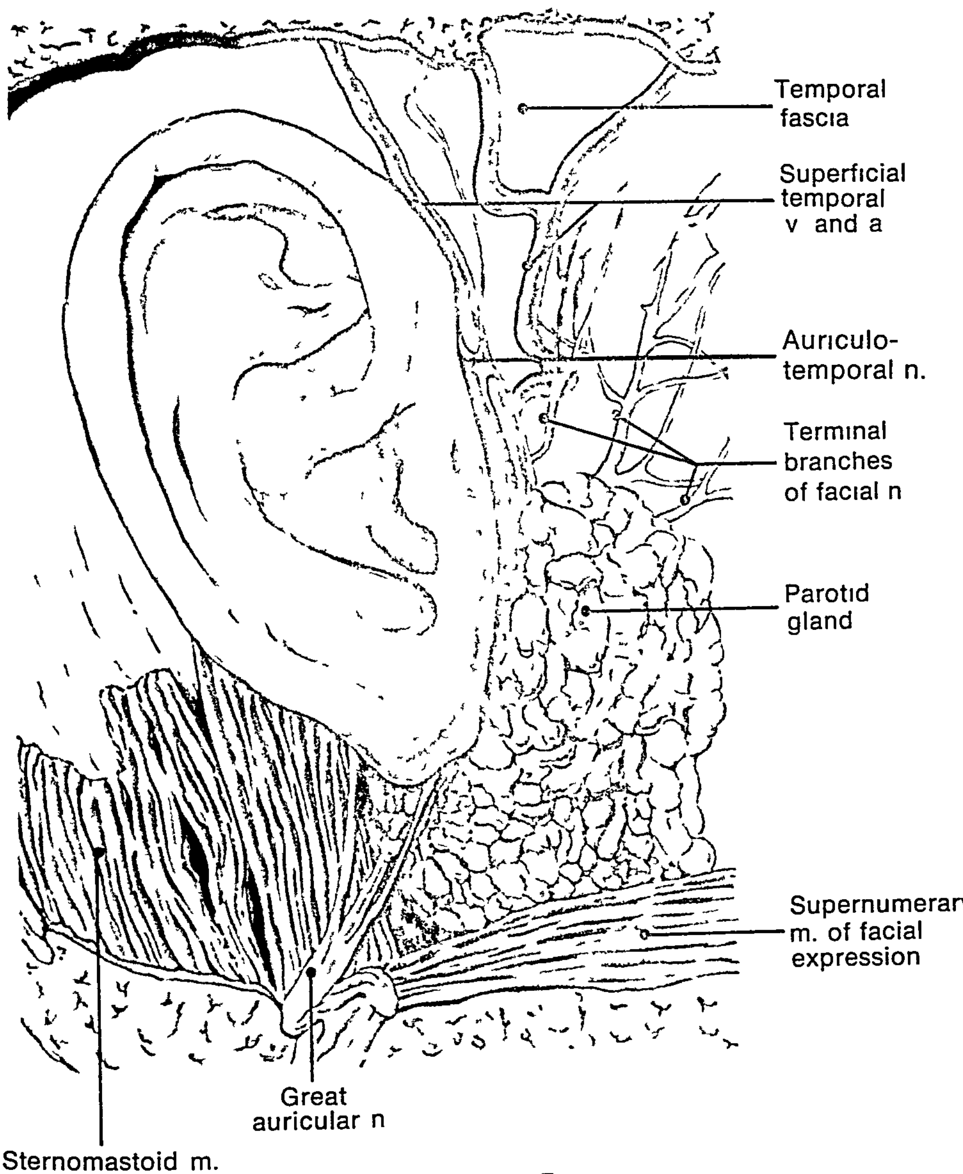


Figure 5.

Figure 6. PERI-AURICULAR REGION (B)

When the parotid gland has been removed, many other structures become exposed. The inferior continuation of the superficial temporal vein is the retromandibular vein. Immediately deep to this vein is the terminal portion and the bifurcation of the external carotid artery. One of the terminal branches, the superficial temporal, before it reaches the level of the tragus, gives off the transverse facial artery, which then proceeds forward in the face. Most of the parotid gland is traversed by the numerous branches of the facial nerve, which, both within the gland as well as after emerging from it, exchange a considerable number of communicating rami. The auriculotemporal nerve, during its course through the gland, is joined to the branches of the facial nerve by several rami.

On a deeper plane, the anterior aspect of the auricle faces the temporomandibular joint and the posterior margin of the ramus of the mandible. Further anteriorly, it is related to the masseter muscle. Above this level, the auricle overlies a thick part of the temporal fascia.

REFERENCES

Brunner, H Zur makroskopischen Form der Glandula parotis Anat Anz, *110* 327–335, 1962

Davis, R A, Anson, B J, Budinger, J M, and Kurth, L E Surgical anatomy of the facial nerve and parotid gland based upon a study of 350 cervicofacial halves Surgery Gynec Obstet, *102* 385–412, 1956

Garin, C Signification de l'anastomose entre le nerf auriculo-temporal et la branche temporo-faciale du nerf facial Archs Anat Histol Embryol, *48* 47–76, 1965

McKenzie, J The parotid gland in relation to the facial nerve J Anat, London, *82* 183–186, 1918

McWhorter, G L The relations of the superficial and deep lobes of the parotid gland to the ducts and to the facial nerve Anat Rec, *12* 149–154, 1917

Patey, D H, and Ranger, I Some points in the surgical anatomy of the parotid gland Br J Surg, *45* 250–258, 1957

Rauch, S *Die Speicheldrüsen des Menschen Anatomie, Physiologie und klinische Pathologie* Thieme, Stuttgart, 1959

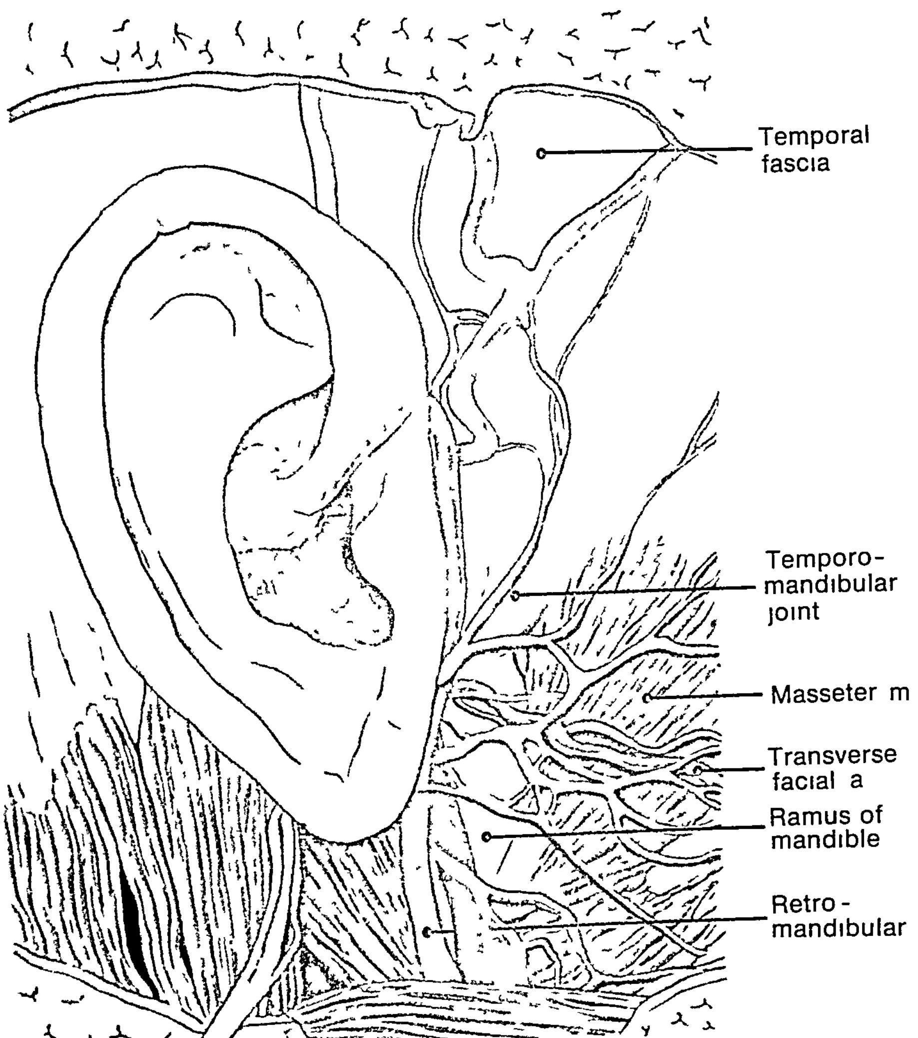

Temporal fascia
Temporo-mandibular joint
Masseter m
Transverse facial a
Ramus of mandible
Retro-mandibular v

Figure 6.

Figure 7. PERI-AURICULAR REGION (C)

To place in better evidence the relationship between the auricle and various muscles of the head and neck, all the related blood vessels, nerves, and fasciae have been removed. The closest bony landmark in front of the tragus is the root of the zygomatic process of the temporal bone, followed by the head of the mandible in the temporomandibular joint, covered by the articular capsule. The auricle as a whole overlies a part of the temporal muscle above, and a part of the sternomastoid muscle below. Deep to the mastoid insertion of the sternomastoid is the origin of the posterior belly of the digastric muscle. This belly extends anteriorly and inferiorly, and becomes continuous with the middle tendon, which in turn gives way to the anterior belly. Still more deeply, three muscles (stylohyoid, styloglossus, and stylopharyngeus) and two ligaments (stylohyoid and stylomandibular) are attached to the styloid process. One of these muscles, the stylohyoid, is related to the superior aspect of the posterior belly of the digastric before it bifurcates to embrace the middle tendon.

FIGURE 7.

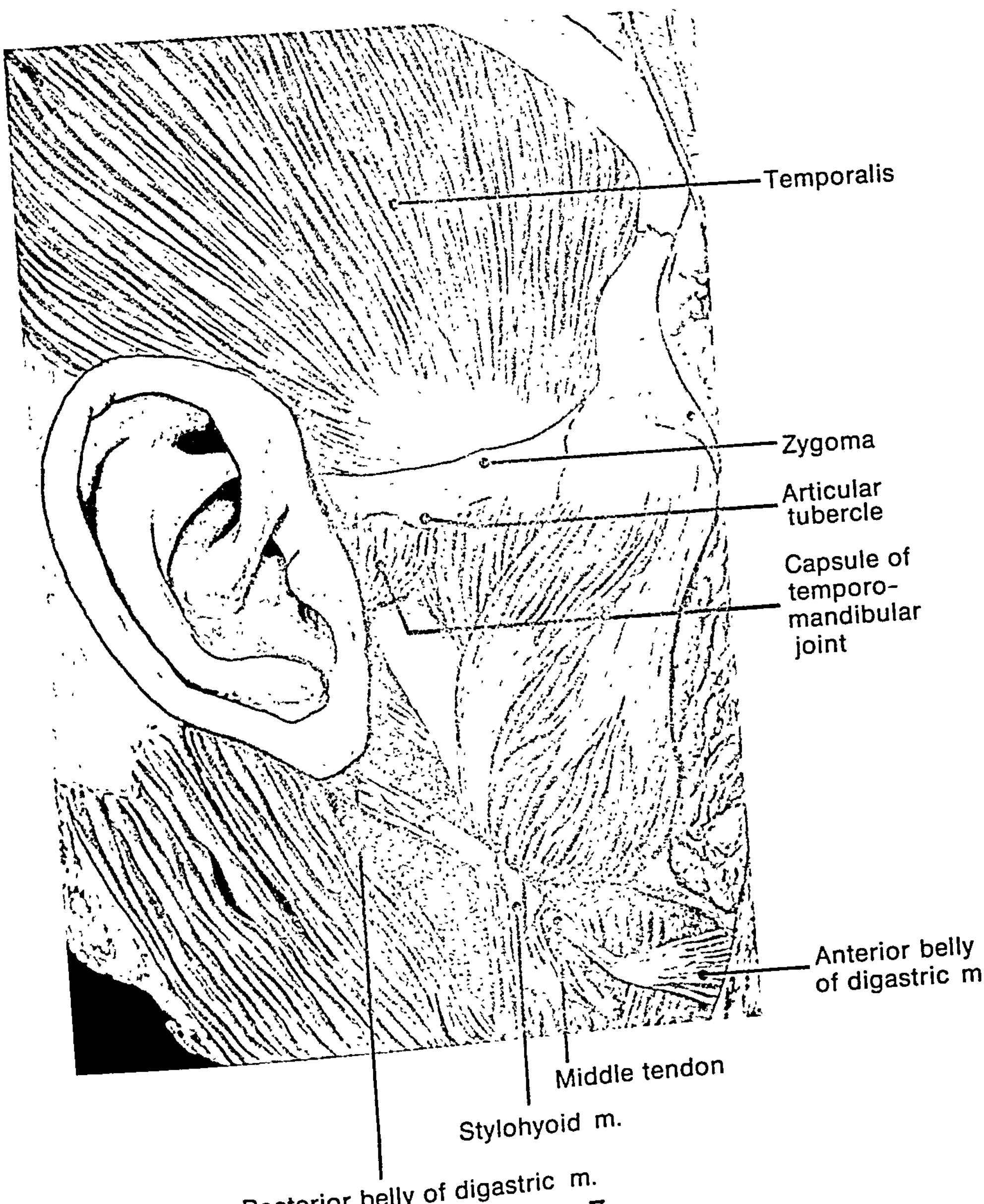


Figure 7.

Figure 8. PERI-AURICULAR REGION (D)

After the articular capsule of the temporomandibular joint has been separated and removed from the articular tubercle, articular disc, and head of the mandible posteriorly, the relationship between the tragus and the components of the joint are demonstrated. The head of the mandible closely approaches the tragus while the mouth is being closed, and an even closer approximation obtains during the movement of retraction. The superior joint compartment is evident when the disc is still *in situ*, whereas the inferior compartment is best demonstrated by reflecting the disc superiorly.

REFERENCES

Lindblom, G. On the anatomy and function of the temporomandibular joint. Acta odont. scand., *17*, Suppl. *28*:1–287, 1960.

Moffett, B. C., Johnson, L. C., McCabe, J. B., and Askew, H. C. Articular remodeling in the adult human temporomandibular joint. Am. J. Anat., *115*:119–141, 1964.

Rees, L. A. The structure and function of the mandibular joint. Br. dent. J., *96*:125–133, 1954.

Sarnat, B. G. (Ed.). *The Temporomandibular Joint.* Thomas, Springfield, Ill., 2nd ed., 1964.

Thilander, B. The structure of the collagen of the temporo-mandibular disc in man. Acta odont. scand., *22*:135–149, 1964.

Zenker, W. Das retroarticuläre plastische Polster des Kiefergelenkes und seine mechanische Bedeutung. Z. Anat. EntwGesch., *119*:375–388, 1956.

FIGURE 8.

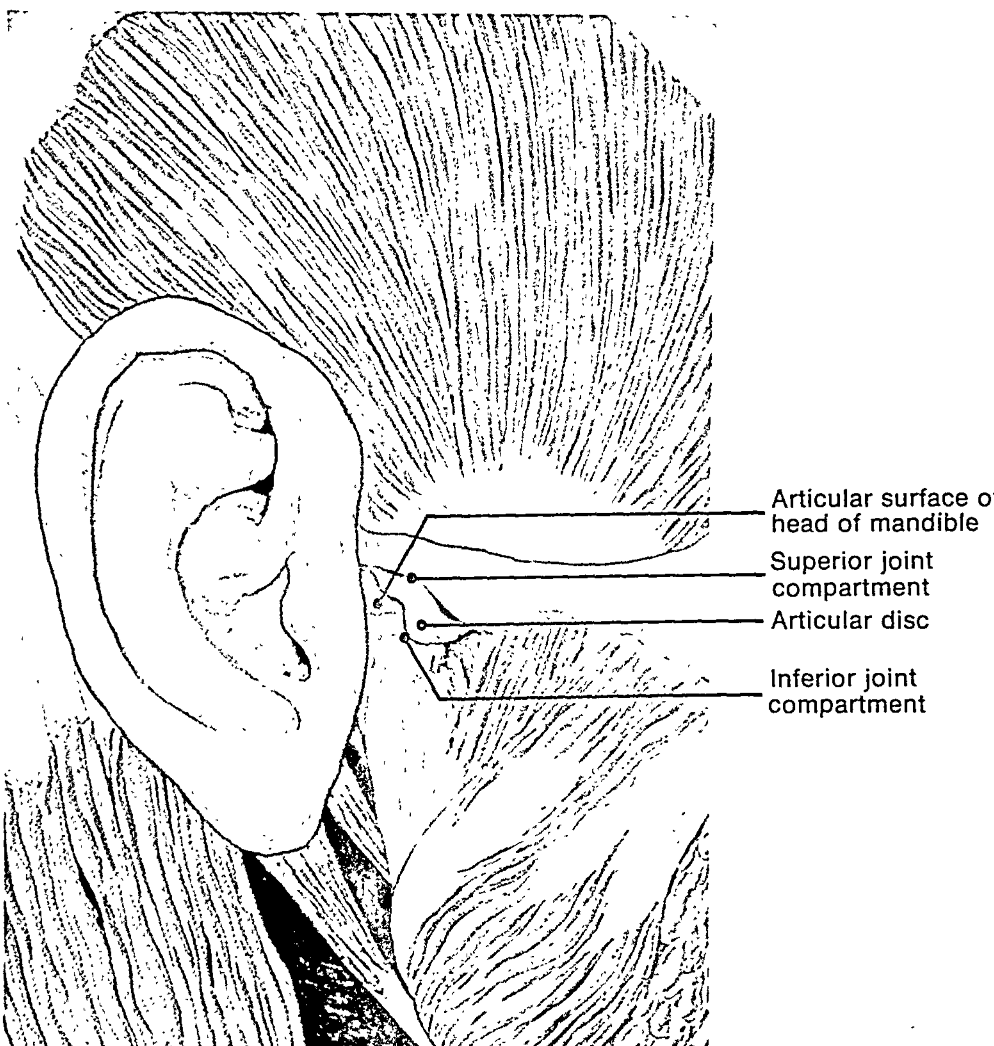


Figure 8.

Figure 9. PERI-AURICULAR REGION (E)

By removal of all the cartilage, the bony external acoustic meatus has been exposed. In the absence of the auricle, the close relationship between the deeper portion of the external ear and the temporomandibular joint becomes more obvious. The tympanic part of the temporal bone serves for the attachment of the cartilaginous external acoustic meatus, and hence of the auricle. The bony meatus is formed largely by the tympanic part of the temporal bone, but its roof and the adjacent portion of its posterior wall are formed by the squamous temporal. The squamotympanic fissure is evident. The external acoustic meatus is related, superiorly, to the supramastoid crest and the posterior root of the zygomatic arch; anterosuperiorly, to the postglenoid tubercle; posterosuperiorly, to the suprameatal triangle, which corresponds to the uppermost part of the concha of the auricle and which indicates the site of the underlying mastoid antrum; anteriorly, to the head of the mandible; posteriorly, to the mastoid portion of the temporal bone; and inferiorly, to the styloid process and its sheath.

Now that the sternomastoid muscle has been removed from the mastoid process, the next deeper muscle, the splenius capitis, which is also attached to the mastoid process, has been brought into view. The other muscles, exposed below the posterior belly of the digastric, belong to the various layers of the back of the neck.

REFERENCE

Kudo, H. Topography of the human labyrinth in the temporal bone. Acta anat., *60*:84–106, 1965.

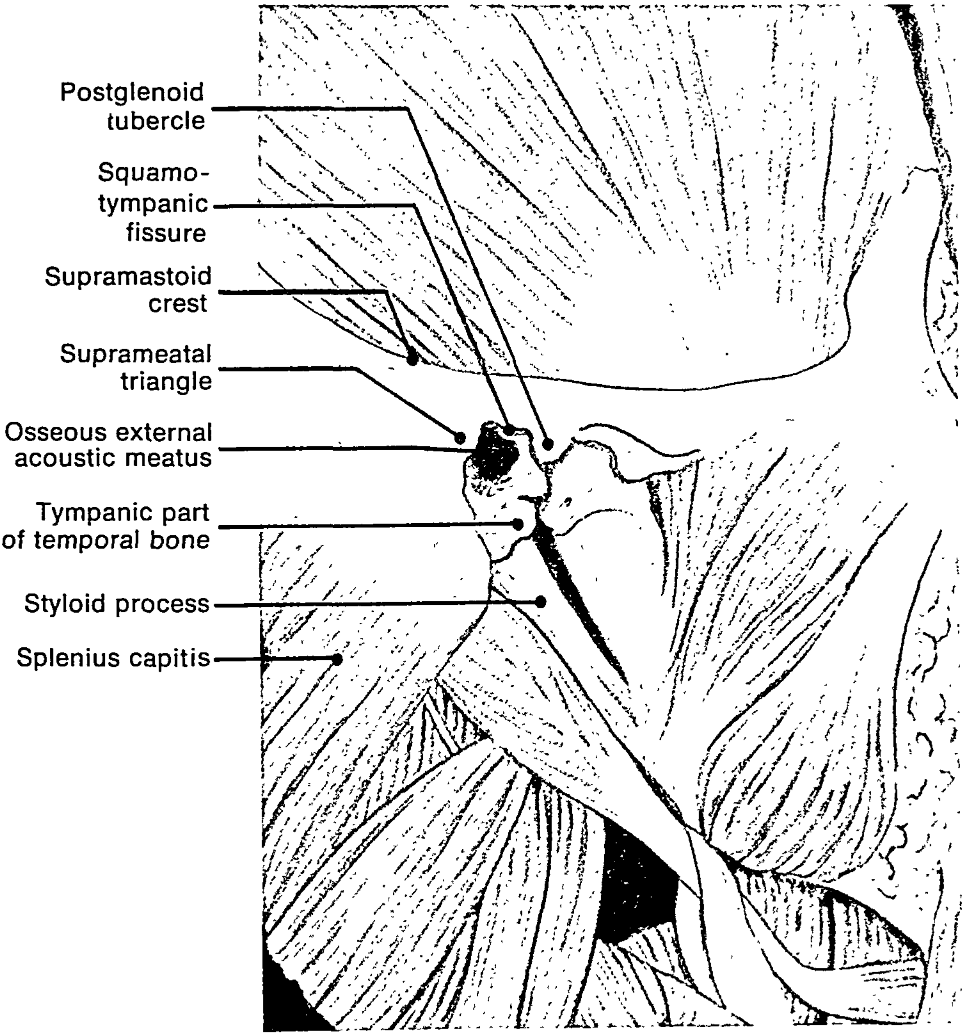

Postglenoid tubercle
Squamo-tympanic fissure
Supramastoid crest
Suprameatal triangle
Osseous external acoustic meatus
Tympanic part of temporal bone
Styloid process
Splenius capitis

Figure 9.

Figure 10. MASTOID CELLS AND EXTERNAL ACOUSTIC MEATUS

Upon removal of the external, compact layer of the mastoid process, above the attachment of the splenius capitis, the most superficial mastoid cells are brought into view. During this procedure, the squamous component of the external acoustic meatus and the adjacent mastoid temporal are partially damaged. The tympanic component, which displays a close relationship to the head of the mandible, remains intact.

The squamotympanic fissure is evident. Medially, it bifurcates to enclose a portion of the tegmen tympani (a part of the petrous temporal). The fissure is thereby divided into a petrosquamous fissure in front and a petrotympanic fissure behind. The petrotympanic fissure allows the exit of the chorda tympani from the skull, together with the anterior ligament of the malleus.

REFERENCES

Batson, O. V. The applied anatomy of the temporal bone. Chapter 2 in H. P. Schenck (Editor), *Otolaryngology*. Prior, Hagerstown, Maryland, Volume 1, 1966.

Bossy, J., and Gaillard, L. Les vestiges ligamentaires du cartilage de Meckel. Acta anat., *52*:282–290, 1963.

Burch, J. G. The cranial attachment of the sphenomandibular (tympanomandibular) ligament. Anat. Rec., *156*:433–438, 1966.

Pannier, M. La pneumatisation de la mastoïde. Etude radio-anatomique. C. r. Ass. Anat., *55*:481–486, 1970.

Stelter, G. P., Bast, T. H., and Anson, B. J. The developmental and adult anatomy of the air-cells in the petrous part of the temporal bone. Q. Bull. NWest. Univ. med. Sch., *34*:23–37, 1960.

FIGURE 10.

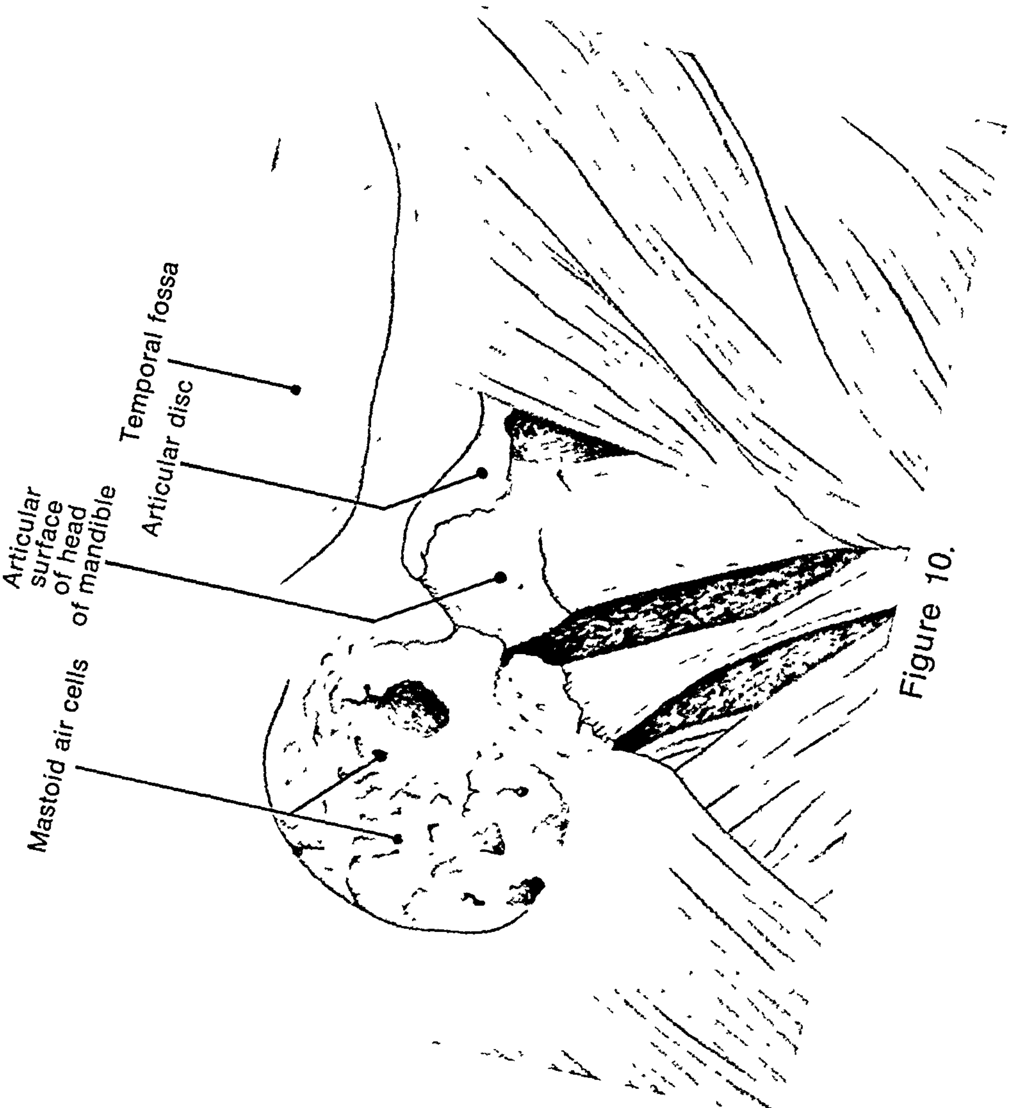


Figure 10.

Figure 11. FACIAL NERVE AND CHORDA TYMPANI

After more bone has been removed around the external acoustic meatus, the lateral surface of the tympanic membrane is revealed. The membrane is surrounded by the tympanic ring, above which an "attic," the epitympanic recess, has been exposed. The upper parts of the malleus and incus can be found within the recess. The main portion of the tympanic cavity is sometimes termed the mesotympanum, the upper and lower parts being referred to as the epitympanic and hypotympanic recesses, respectively.

Many more air cells have been opened in the mastoid region. The communication, aditus ad antrum, between the epitympanic recess and the mastoid antrum is evident. Between the antrum and the lateral semicircular canal, the facial nerve turns downwards within its own bony tunnel, the facial canal. The nerve has been exposed in its downward course through the bone, as it descends to the stylomastoid foramen. Before the nerve leaves the skull, however, it gives off the chorda tympani, which runs through the bone superiorly, anteriorly, and medially to enter the tympanic cavity.

The facial nerve, in its intra-osseous course, is generally considered in three segments; these have been named the labyrinthine, tympanic, and mastoid parts of the nerve. The labyrinthine part proceeds laterally and slightly anteriorly from the fundus of the internal acoustic meatus, and then enlarges to form the geniculate ganglion. The tympanic part of the nerve extends posteriorly from the ganglion as far as the level of the base of the pyramidal eminence. The mastoid part of the nerve descends through the mastoid part of the temporal bone to reach the stylomastoid foramen.

REFERENCES

Anson, B. J., Donaldson, J. A., Warpeha, R. L., and Rensink, M. J. The facial nerve, sheath and blood supply in relation to the surgery of decompression. Ann. Otol. Rhinol. Lar., *79*:710–727, 1970.

Batson, O. V. The usual course and relations of the Nervus facialis and the practically important variations. Archs Otolar., *14*:114–115, 1931.

Winckler, G. Le nerf facial. Morphologie, topographie, structure et systématisation fonctionnelle. C. r. Ass. Anat., *50*:11–50, 1965.

FIGURE 11.

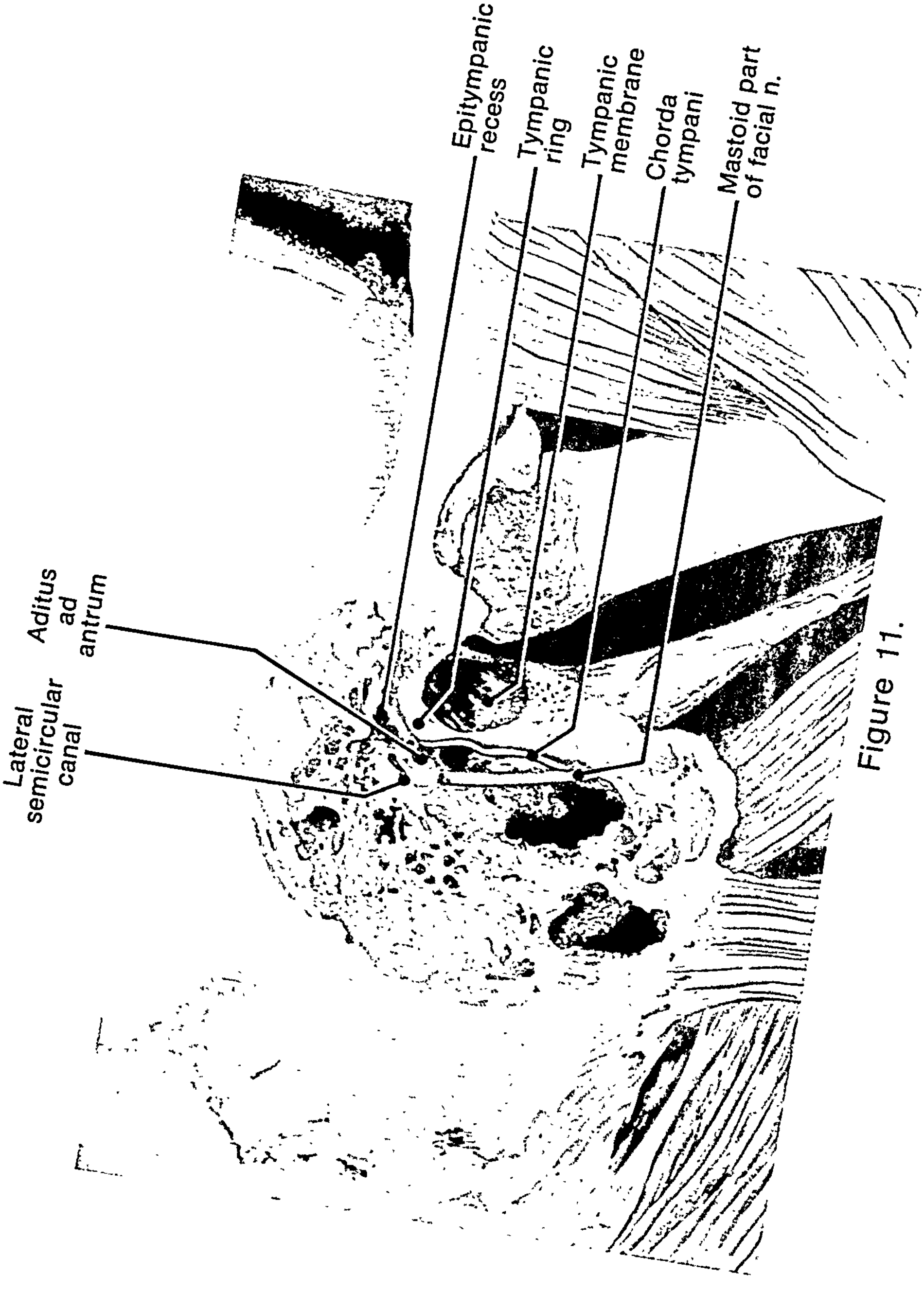


Figure 11.

Figure 12. FACIAL NERVE AND EPITYMPANIC RECESS

After some further removal of bone above the tympanic ring, better exposure of the epitympanic recess and of part of the medial wall of the tympanic cavity has been obtained. The head of the malleus and the body and short crus of the incus can be seen *in situ* in the epitympanic recess. The most posterior part of the short crus overlies the bony boundary of the aditus.

The lateral semicircular canal, on the medial wall of the tympanic cavity, has been completely opened from the lateral side. Through this operation, the topographical relationship of the semicircular canal to the incus and the malleus is clearly demonstrated.

REFERENCE

Harty, M. Some anatomical points in the fenestration operation. J. Lar. Otol., *62*:36–38, 1948.

FIGURE 12.

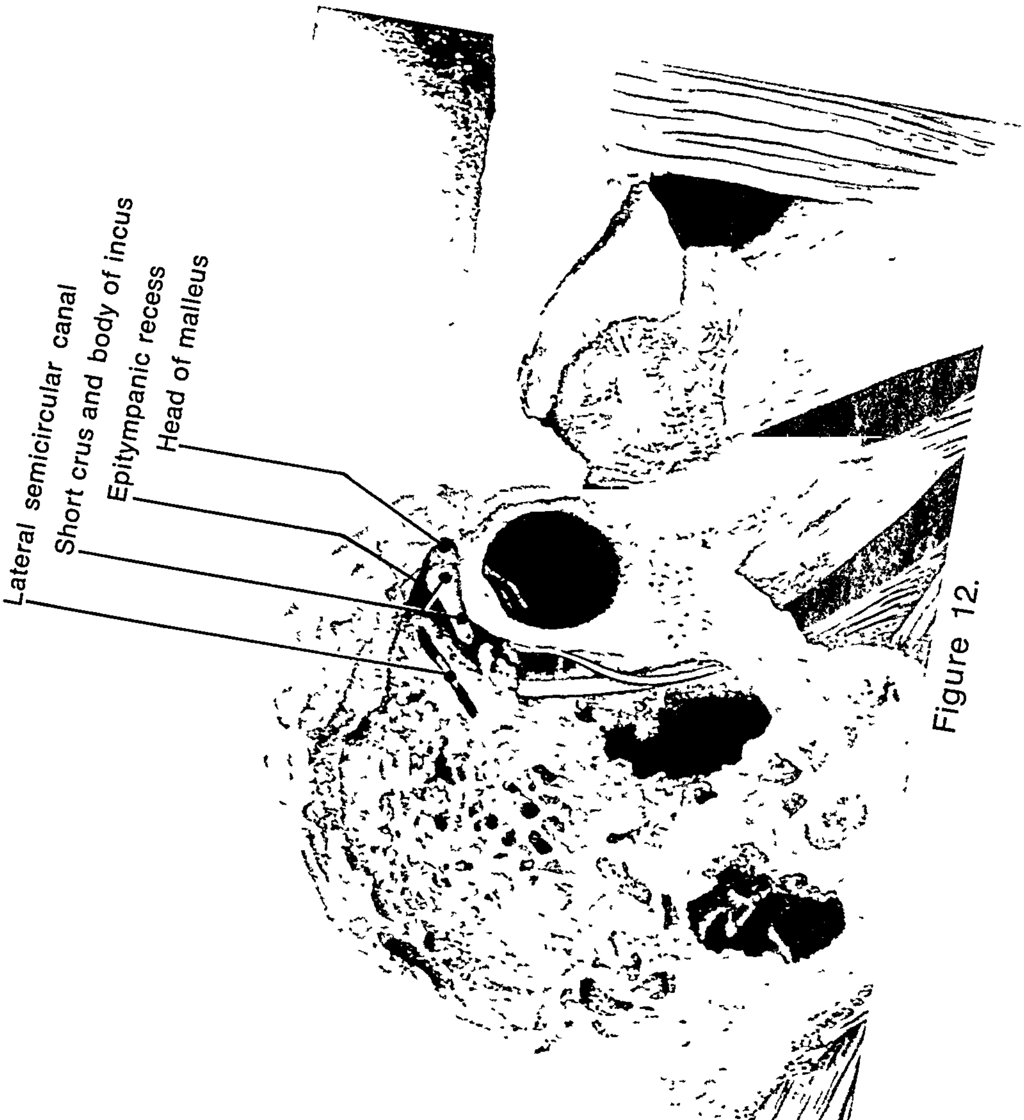


Figure 12.

Figure 13. FACIAL NERVE AND TYMPANIC RING

In order to demonstrate the degree of accessibility of the auditory ossicles through the external acoustic meatus and the tympanic membrane, the membrane has been removed, thereby displaying the intimate relationships between the ossicles and the medial end of the meatus. The head of the malleus is lodged in the epitympanic recess, whereas its neck is overlapped laterally by the tympanic ring. The remainder of the malleus, consisting of the lateral and anterior processes and the handle, would be covered laterally *in vivo* by the tympanic membrane. At a deeper level within the tympanic cavity, the long crus of the incus and the incudostapedial joint can be seen through the tympanic ring. Still more deeply, the promontory on the medial wall of the tympanic cavity has been partially exposed.

FIGURE 13.

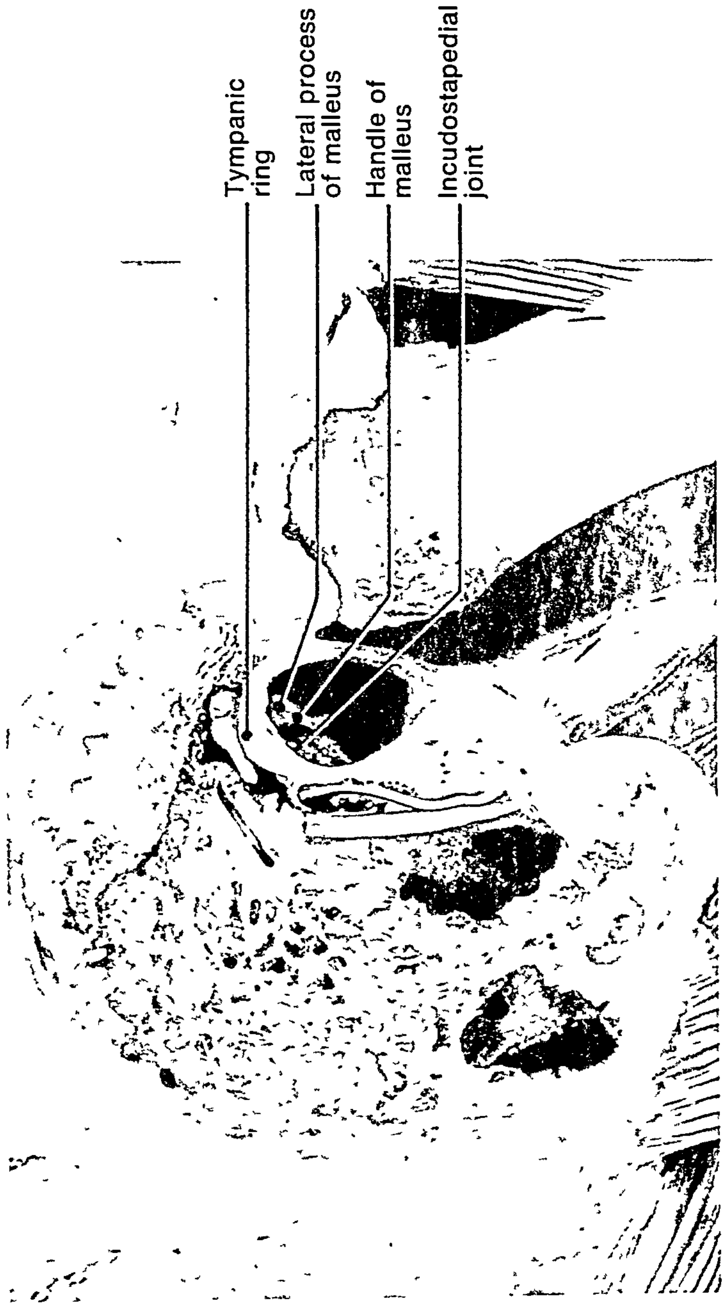


Figure 13.

Figure 14. CHORDA TYMPANI AND AUDITORY OSSICLES

In order to see the intimate relationships between the individual auditory ossicles *in situ,* the upper half of the tympanic ring has been removed. The malleus is still maintained in its normal position by means of the tensor tympani and the anterior ligament. This ligament has been exposed anteriorly as far as the petrotympanic fissure. The incus is secured in its proper position by its connections with the other ossicles at the incudomallear and incudostapedial joints. The successive relationships of the chorda tympani to the incus, the malleus, and the anterior ligament can be seen. After traversing the tympanic cavity, the chorda tympani re-enters the temporal bone anteriorly, and finally emerges through the petrotympanic fissure.

FIGURE 14.

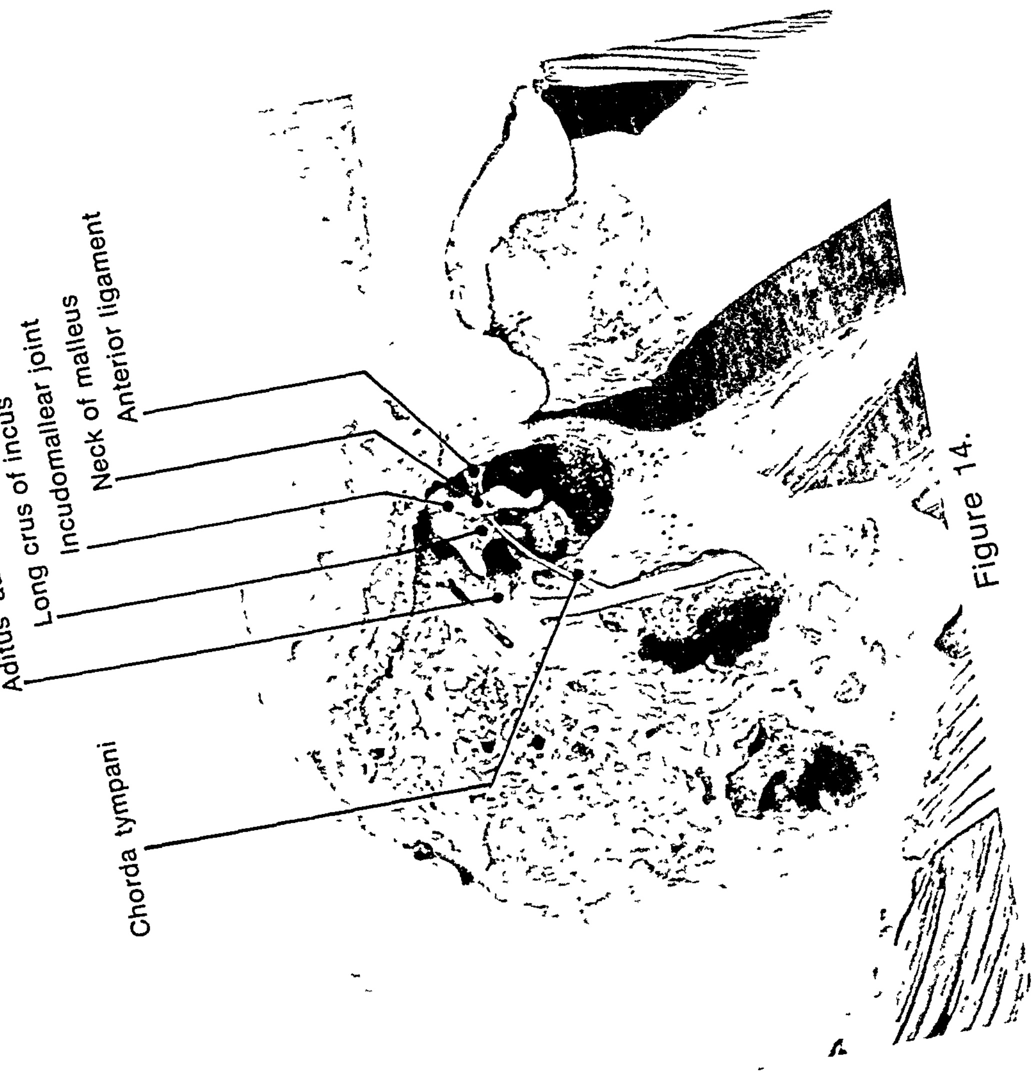


Figure 14.

Figure 15. MEDIAL WALL OF TYMPANIC CAVITY

The mandible has now been removed from the temporomandibular joint. The osseous part of the auditory tube has been opened from the lateral side as far anteriorly as the petrotympanic fissure. The tensor tympani, still in its bony semicanal, lies above the exposed auditory tube.

The malleus has been detached from the tendon of the tensor tympani, disarticulated at the incudomallear joint, and removed together with its ligaments and the chorda tympani. Similarly, the incus, after disarticulation from the stapes, has been taken away.

On the medial wall of the tympanic cavity, the promontory and a part of the fenestra cochleae can be detected. The promontory is formed by the basal turn of the cochlea (see Fig. 35). Approaching the surface of the promontory from below and behind, first the tympanic nerve and then the tympanic plexus can be seen. One of the collateral branches of the plexus, the tubal, extends anteriorly along the medial wall of the bony part of the tube. The terminal branch of the plexus, the lesser petrosal nerve, winds deep to the cochleariform process and continues its course medial to the tensor tympani.

Above and behind the promontory, parallel to and below the lateral semicircular canal, the prominence of the facial canal projects into the tympanic cavity.

REFERENCES

Altmann, F. Malformations of the Eustachian tube, the middle ear, and its appendages. Archs Otolar., *54*:241–266, 1951.

Cochet, B. Contribution à l'étude du plexus tympanique. Archs Anat. Histol. Embryol., *40*:1–48, 1967.

Etter, L. E. *Roentgenography and Roentgenology of the Middle Ear and Mastoid Process* Thomas, Springfield, Ill., 1965.

Kirikae, I. *The Structure and Function of the Middle Ear.* University of Tokyo Press, Tokyo, 1960.

Kobrak, H. G. *The Middle Ear.* University of Chicago Press, Chicago, 1959.

Lim, D. J., and Hussl, B. Human middle ear epithelium. Archs Otolar., *89*:835–849, 1969.

Proctor, B. Surgical anatomy and embryology of the middle ear. Trans. Am. Acad. Ophthal. Otolar., 801–814, 1963.

Winckler, G., and Cochet, B. La systématisation du nerf tympanique (nerf de Jacobson). C. r. Ass. Anat., *52*:1215–1221, 1968.

Yates, A. L. The anatomy of the middle ear. Proc. R. Soc. Med., *29*:837–840, 1936.

FIGURE 15.

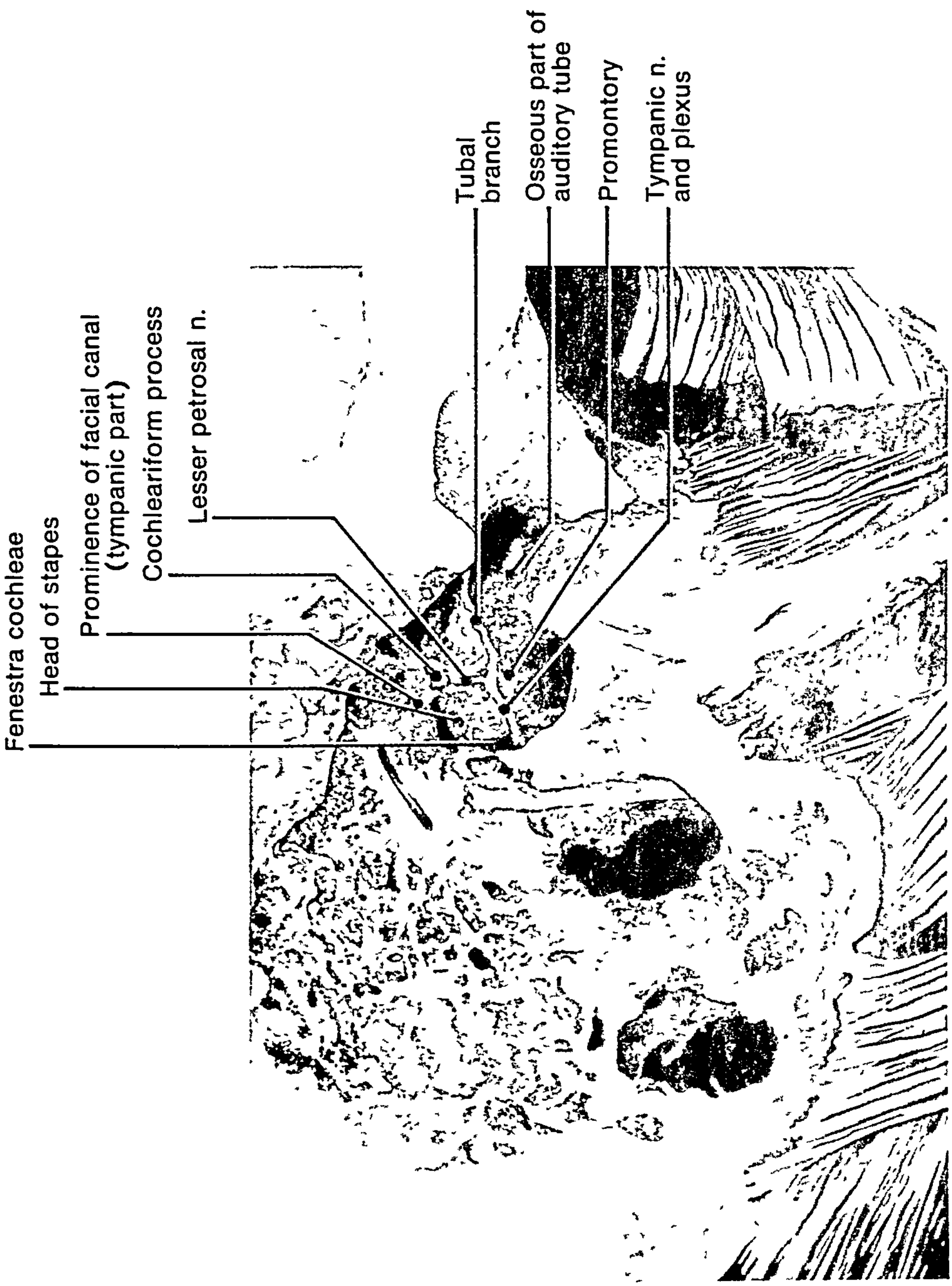


Figure 15.

Figure 16. FACIAL NERVE AND STAPEDIUS

The subdivision of the intra-osseous course of the facial nerve into labyrinthine, tympanic, and mastoid parts has been mentioned in the description of Figure 11. The tympanic part of the nerve has now been exposed from the cochleariform process, which is immediately behind the geniculate ganglion, as far as the continuation of the nerve into its mastoid part. The facial nerve is easily exposed because it is covered by only a thin, bony lamina, which, in many instances, presents a number of dehiscences.

Within the curve of the facial nerve formed by its tympanic and mastoid parts, the pyramidal eminence has been removed, thereby exposing the stapedius and its tendon. The close relationship between the fenestra vestibuli and the facial canal will become evident as the base of the stapes is approached (Fig. 18).

Now that the bony lamina covering the lateral aspect of the tensor tympani has been taken away, the posterior half of the muscle and its tendon can be seen *in situ*.

The tympanic cavity, which contains the auditory ossicles, is in communication with (1) the mastoid air cells and the mastoid antrum by way of the aditus, and (2) the nasopharynx by way of the auditory tube. The antrum, the tympanic cavity, and the auditory tube are roofed by the tegmen tympani. The tympanic cavity and the auditory tube develop as a recess of the embryonic pharynx.

REFERENCES

Anson, B. J. Die Embryologie und Anatomie des Facialiskanals und des Facialisnerven. Arch. Ohr.-, Nas.- u. KehlkHeilk., *184*:269–284, 1965.

Anson, B. J., Harper, D. G., and Warpeha, R. L. Surgical anatomy of the facial canal and facial nerve. Ann. Otol. Rhinol. Lar., *72*:713–734, 1963.

Dietzel, K. Über die Dehiszenzen des Facialiskanals. Z. Lar. Rhinol. Otol., *40*:366–379, 1961.

Fowler, E. P. Variations in the temporal bone course of the facial nerve. Laryngoscope, St Louis, *71*:937–946, 1961.

Kley, W. Nervus facialis und Mittelohr. Z. Lar. Rhinol. Otol., *40*:409–413, 1961.

Wright, J. W., Taylor, C. C., and McKay, D. C. Variations in the course of the facial nerve as illustrated by tomography. Laryngoscope, St Louis, *77*:717–733, 1967.

FIGURE 16.

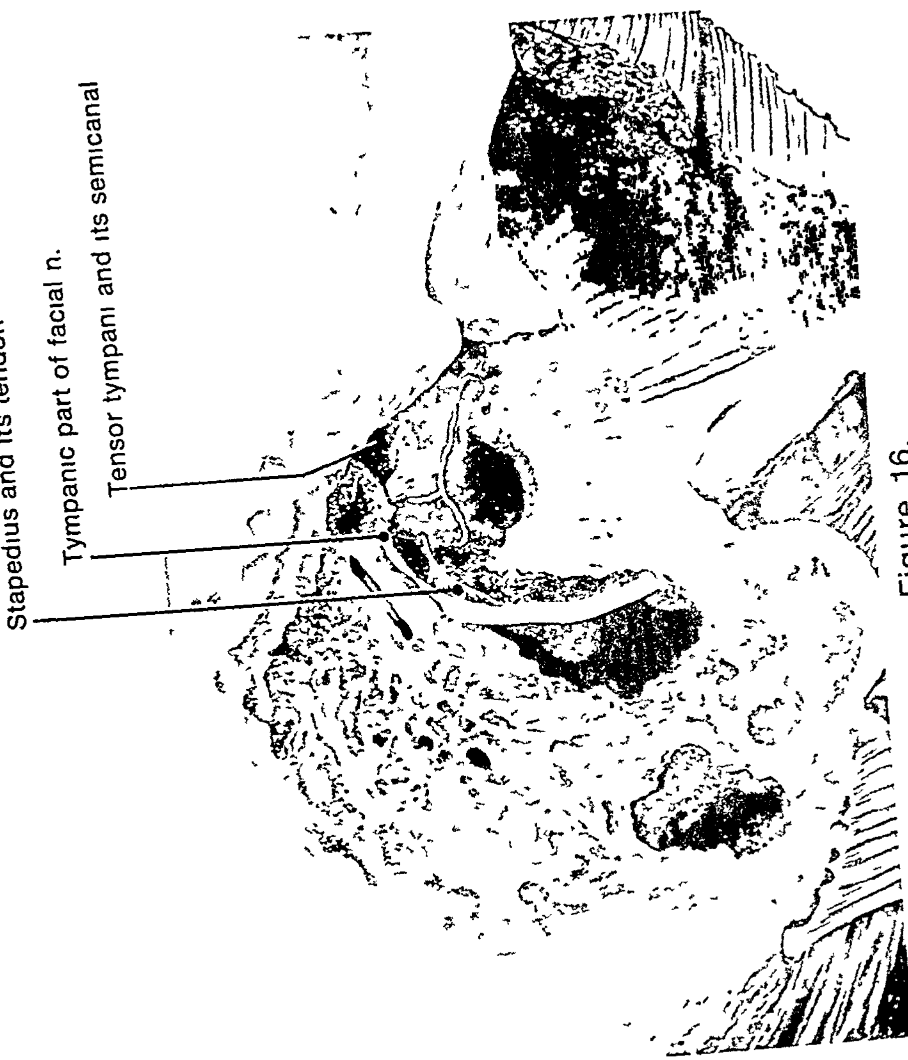


Figure 16.

Figure 17. STAPEDIUS

The entire lateral aspect of the stapedius has been exposed by reflecting the facial nerve anteriorly, and the remainder of the pyramidal eminence has been removed. The stapedius is continued anteriorly as a narrow tendon attached to the neck of the stapes adjacent to the incudostapedial joint. The stapedius is supplied by the facial nerve.

A retrotympanic recess, known as the sinus tympani, may extend posteriorly, medial to the pyramidal eminence and the facial nerve.

REFERENCES

Anson, B. J., Donaldson, J. A., Warpeha, R. L., and Winch, T. R. The surgical anatomy of the ossicular muscles and the facial nerve. Laryngoscope, St Louis, *77*:1269–1294, 1967.

Donaldson, J. A., Anson, B. J., Warpeha, R. L., and Rensink, M. J. The surgical anatomy of the sinus tympani. Archs Otolar., *91*:219–227, 1970.

Platzer, W. Zur Anatomie der Eminentia pyramidalis und des M. Stapedius. Mschr. Ohrenheilk. Lar.-Rhinol., *95*:553–564, 1961.

Terracol, J., Granel, F., Winckler, G., and Ardouin, P. L'innervation proprioceptive en oto-laryngologie. Anns Oto-lar., *82*:525–533, 1965.

FIGURE 17.

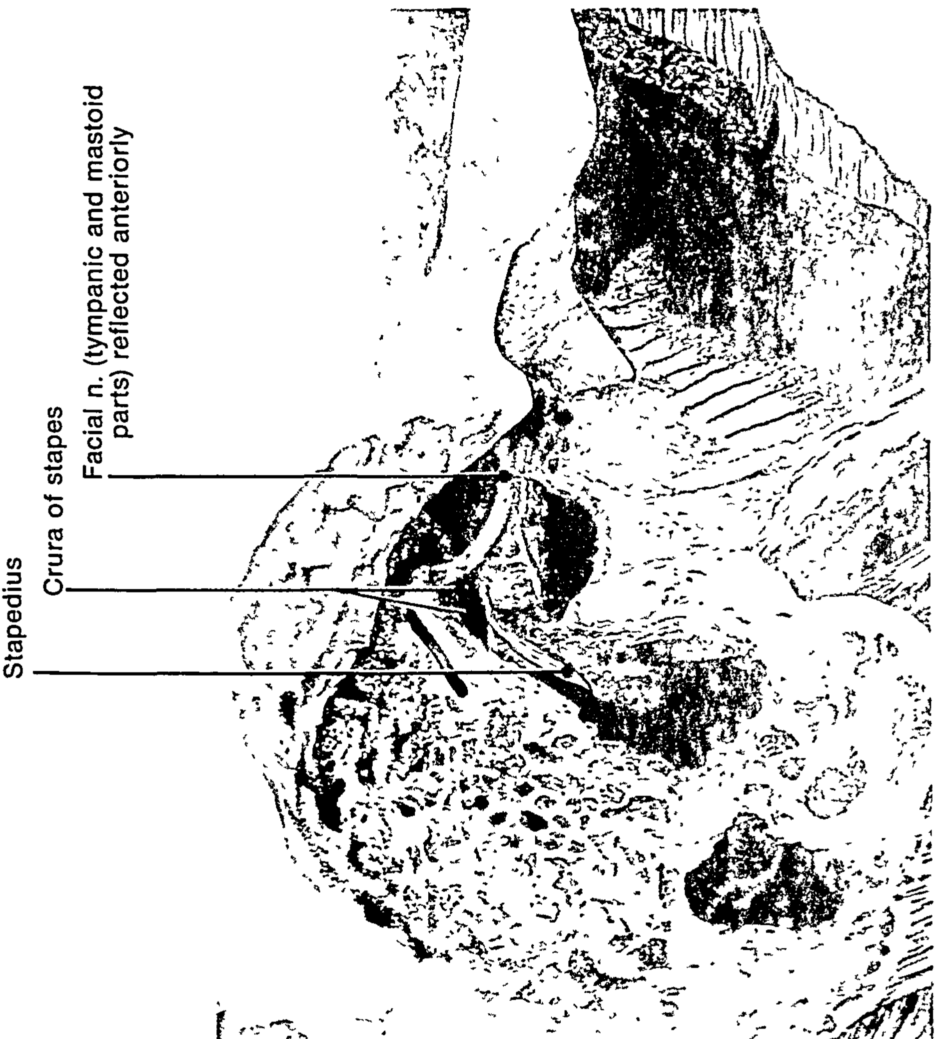


Figure 17.

Figure 18. STAPES IN FENESTRA VESTIBULI

The medial wall of the tympanic cavity presents two "windows:" the fenestra vestibuli ("oval window"), closed by the base of the stapes, and the fenestra cochleae ("round window"), closed by the secondary tympanic membrane.

After removal of the entire stapedius, the stapes can be demonstrated *in situ*. In addition to the head and neck, the crura and the base of the ossicle are also brought into view. Below the stapes, the whole of the fenestra cochleae has now been exposed.

In the continuation of the tympanic cavity anteriorly, more of the bony lamina has been removed from the tensor tympani. Hence, more of the surface of the muscle is shown.

REFERENCES

Engström, H. Über den Bau der Syndesmosis tympano-stapedia beim Menschen und einigen Säugetieren. Acta anat., *6*:283–306, 1948.

Gussen, R. The stapediovestibular joint: normal structure and pathogenesis of otosclerosis. Acta oto-lar., Suppl. *248*:1–38, 1969.

Harty, M. The secondary tympanic membrane and annular ligament. Z. mikrosk.-anat. Forsch., *70*:484–489, 1963.

FIGURE 18.

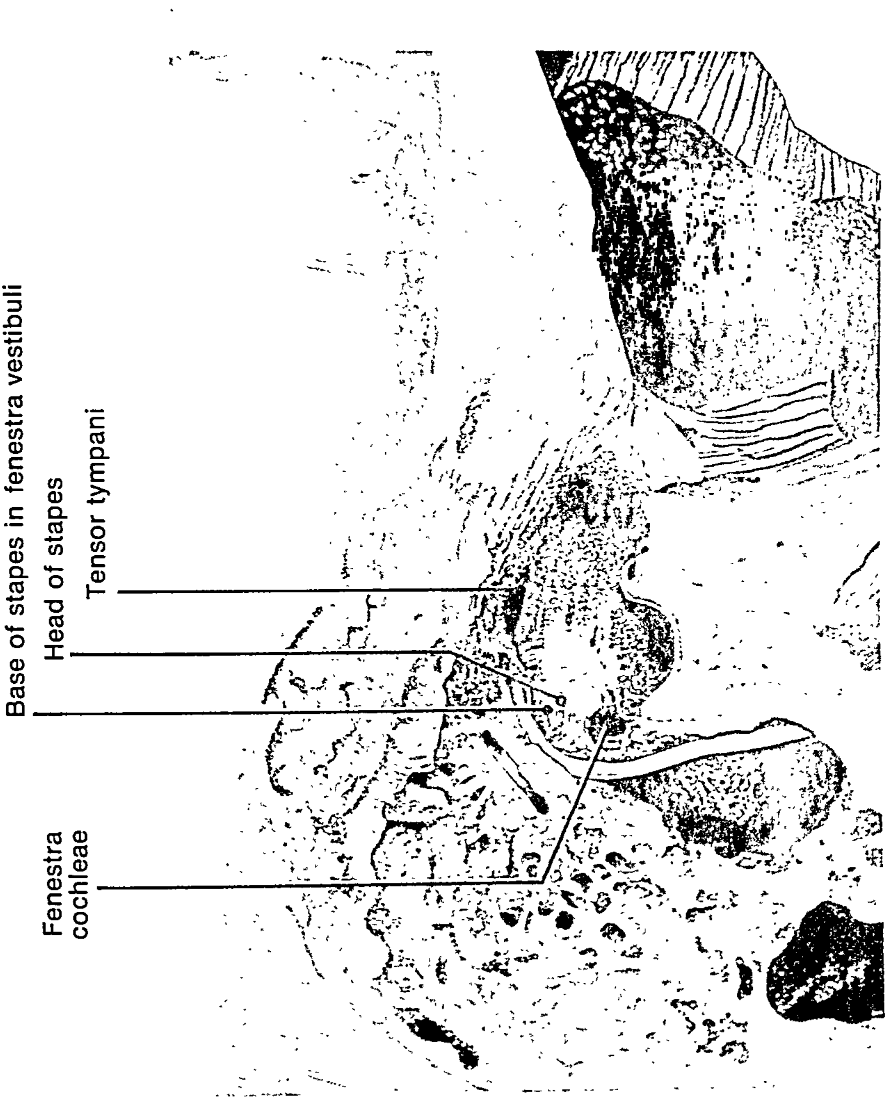


Figure 18.

Figure 19. SEMICIRCULAR CANALS

The facial nerve has been dissected as far anteriorly as the geniculate ganglion and may be considered as a key to the structures now displayed. Above the nerve, a layer of cancellous bone which surrounded the compact zone immediately adjacent to the semicircular canals has been removed from the lateral side. Within the compact zone, the semicircular canals were approached and finally perforated. Each has been opened by removing its lateral boundary. The common crus of the anterior and posterior canals is evident. The tympanic part of the facial nerve and its subsequent curve are very closely related to the lateral and the posterior semicircular canals, respectively.

After extraction of the stapes, the relationship between the facial nerve and both fenestrae becomes more obvious. Now that the tensor tympani has been dissected away, its semicanal, above that for the auditory tube, becomes demonstrable. The bony septum between the two semicanals protrudes laterally.

It should be appreciated that the lateral semicircular canal is not horizontal; hence, it is incorrect to refer to it as such.

FIGURE 19.

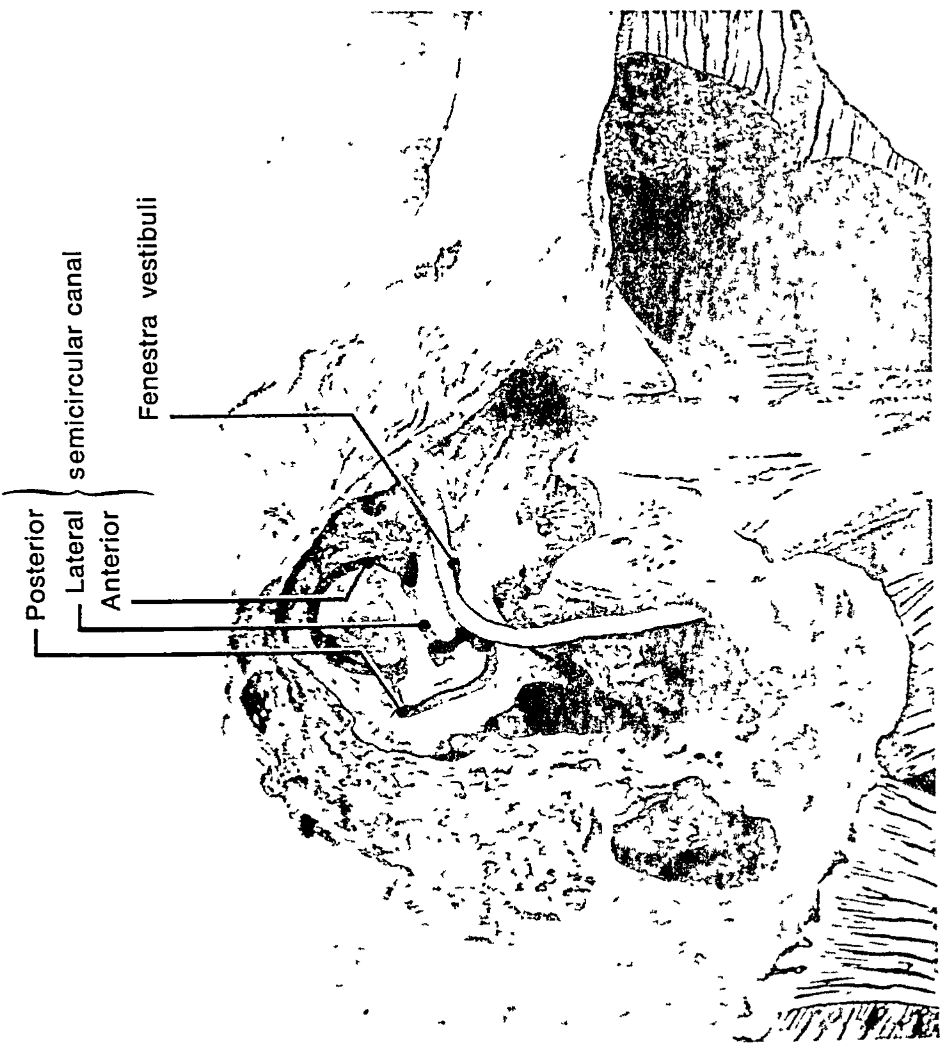


Figure 19.

Figure 20. EPITYMPANIC RECESS

This dissection of a dried skull, without the mandible, demonstrates the topographical relationship of the tympanic ring to the various spaces associated with the tympanic cavity. Of particular interest are the structures of the middle ear that can be approached through the external acoustic meatus (parts of malleus, incudostapedial joint, chorda tympani, anterior ligament, promontory), and those that become accessible by using the transmastoid route (contents of epitympanic recess, fenestrae, aditus ad antrum, antrum and other air cells). In the latter approach, the intra-osseous course of the chorda tympani must be kept in mind.

FIGURE 20.

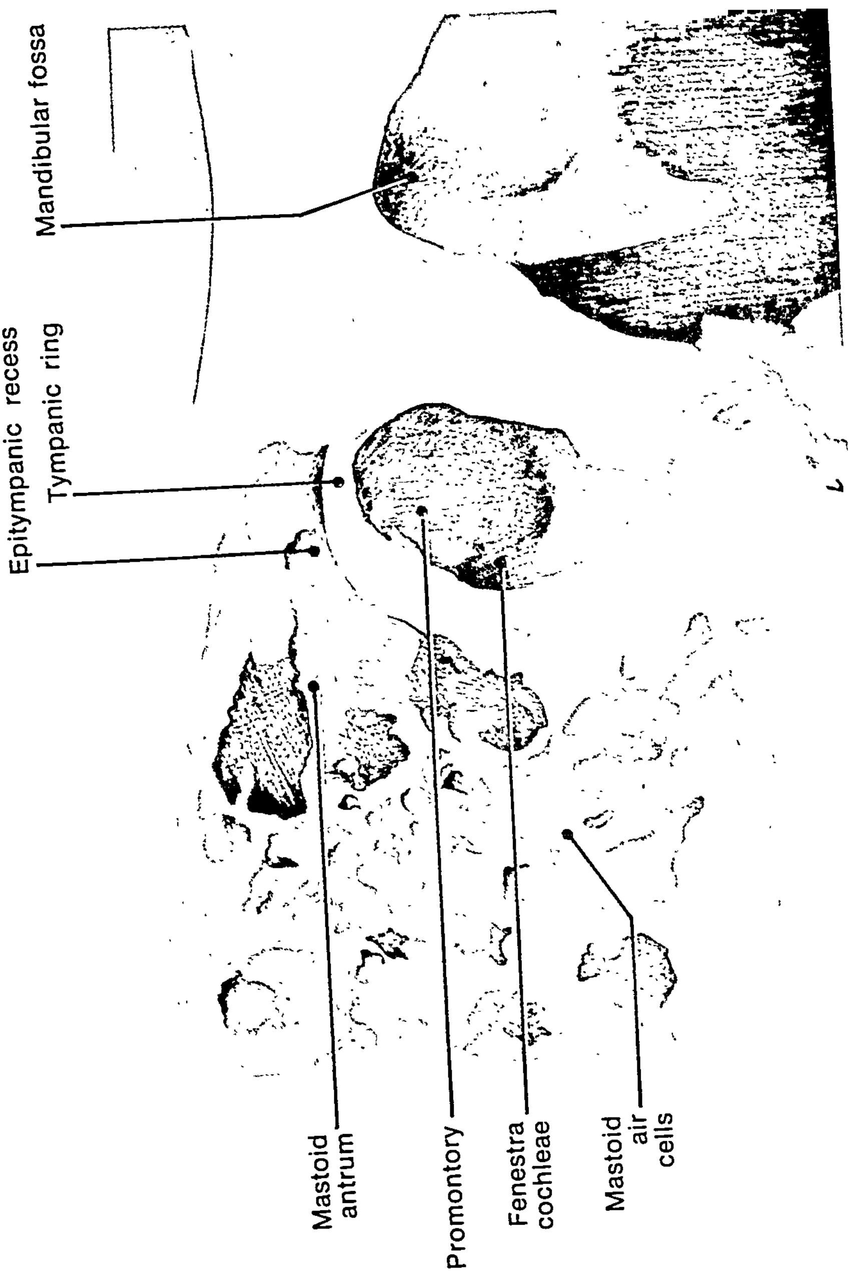


Figure 20.

Figure 21. TYMPANIC MEMBRANE *IN VIVO*

The lateral aspect of the tympanic membrane is accessible to direct vision (otoscopy) by the correct insertion of an illuminated speculum (otoscope, or auriscope) into the external acoustic meatus. Anterosuperiorly, the handle and lateral process can be distinguished. From the prominence formed by the lateral process, anterior and posterior mallear folds extend forwards and backwards, respectively, and separate the uppermost, smaller, highly vascularized flaccid part of the tympanic membrane from the lower, very much larger, almost avascular tense part (Fig. 45). The handle of the malleus forms an elongated prominence that descends inferoposteriorly through the tense part of the membrane. At the tip of this prominence, the membrane is invaginated medially and forms the umbo, which lies approximately opposite the promontory of the middle ear. Behind and parallel with the handle of the malleus, the long process of the incus may occasionally be seen, and the chorda tympani can sometimes be distinguished.

The normal tympanic membrane appears brilliant, pearl-gray in color, adequately translucent, neither retracted nor bulging, and mobile. It reflects a cone of light in its antero-inferior quadrant.

An imaginary line down the handle of the malleus and one at a right angle to it through the umbo are used to delimit quadrants on the tympanic membrane for descriptive purposes.

REFERENCES

Alberti, P W R M Migration of the surface epithelium of the human tympanic membrane Anat Rec, *142* 207–208, 1962

Druss, J G Incisions of drum membrane in otitis media Am J Surg, *36* 102–106, 1937

Levin, V N Besonderheiten der Gefassbahn des Gehororganes beim Menschen Anat Anz, *128* 39–59, 1971

Litton, W B Epidermal migration in the ear [guinea-pig] Acta oto-lar, Suppl *240* 1–39, 1968

Mackenzie, G W The appearance and behavior of the normal tympanic membrane Laryngoscope, St Louis, *34* 497–533, 1924

Quiroz Pavia, F, DeLara Galindo S, and Mercedes, J L Stereoscopic microscopical observations on the innervation of the tympanic membrane Acta anat, 66 481–493, 1967

Saini, V K Vascular pattern of human tympanic membrane Archs Otolar, *79* 193–196, 1964

Schneck, C D, and Kendall, S The collagen fiber arrangement of the tympanic membrane Anat Rec, *157* 317, 1967

FIGURE 21.

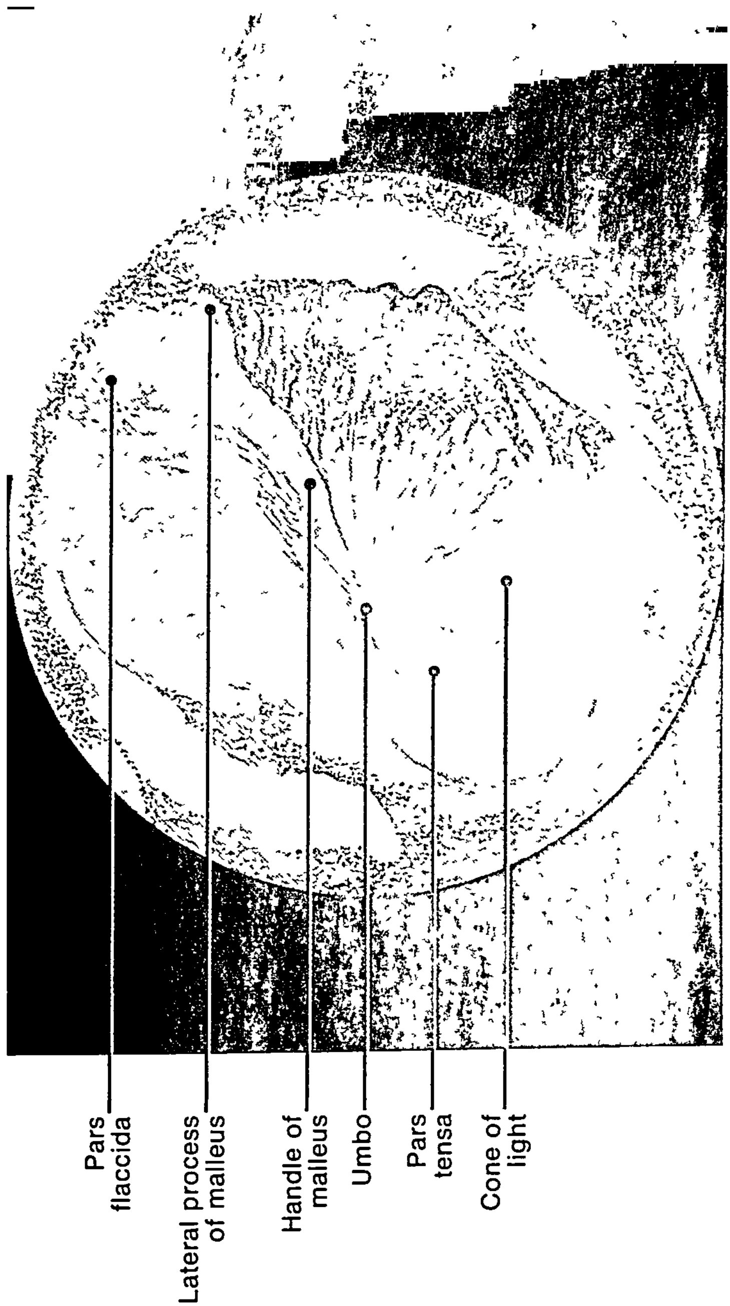


Figure 21.

Figure 22. EXTERNAL ACOUSTIC MEATUS AND MASTOID ANTRUM

This dissection relates the tympanic membrane as a whole to the surrounding features, such as the mandibular fossa and temporomandibular joint, the styloid process, and the mastoid antrum and mastoid cells.

The mastoid antrum has been penetrated by removing several levels of mastoid cells. The intact portion of the mastoid process has been cleared of muscular attachments so that the extra-osseous part of the facial nerve has been brought into view.

REFERENCE

Litton, W. B., Krause, C. J., Anson, B. J., and Cohen, W. N. The relationship of the facial canal to the annular sulcus. Laryngoscope, St Louis, *79*:1584–1604, 1969.

FIGURE 22.

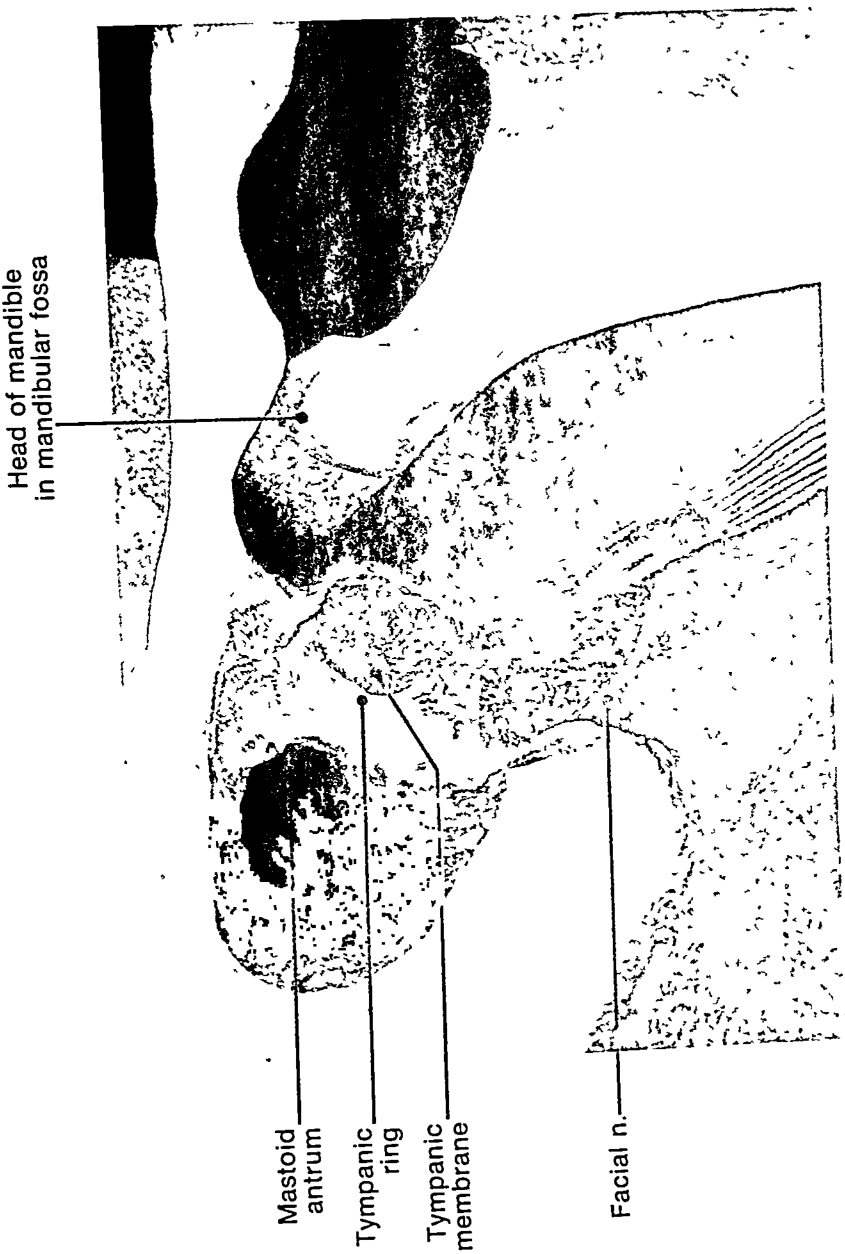


Figure 22.

Figure 23. TYMPANIC RING

Because the bony deposition around the external acoustic meatus is relatively small at birth, the newborn infant has been used to demonstrate some features in this and the next three views.

The facial nerve is very superficial in infants because the mastoid process is absent at birth. This develops gradually during early childhood. On the other hand, the tympanic ring and membrane, the auditory ossicles, the mastoid antrum, and the inner ear have attained essentially their adult size by the time of birth.

After removal of the tympanic membrane, access to the structures of the middle ear is easily obtained without damaging the surrounding bone, owing to the shallowness of the bony meatus. Moreover, because the attachments of the membrane to the ring and to the malleus are relatively loose, the membrane may be separated without in any way disturbing the relationships of the ossicles to each other. From the lateral process of the malleus, the handle extends inferoposteriorly at an angle of about 45 degrees to the horizontal. The only part of the incus that is approachable through the ring is its long crus; its tip, the lenticular process, projects medially to take part in the incudostapedial joint. The extra-osseous portion of the stapedius and its tendon are demonstrated in their entire length from the opening in the pyramidal eminence to the insertion on the neck of the stapes. Some parts of the tympanic plexus can be seen on the promontory, and, on the posterior surface of that prominence, a portion of the fenestra cochleae is evident.

REFERENCES

Rogers, L. Observations on the developmental anatomy of the temporal bone. Ann. Otol. Rhinol. Lar., *30:*103–129, 1921.

Sammarco, G. J., Ryan, R. F., and Longenecker, C. G. Anatomy of the facial nerve in fetuses and stillborn infants. Plast. reconstr. Surg., *37:*566–574, 1966.

FIGURE 23.

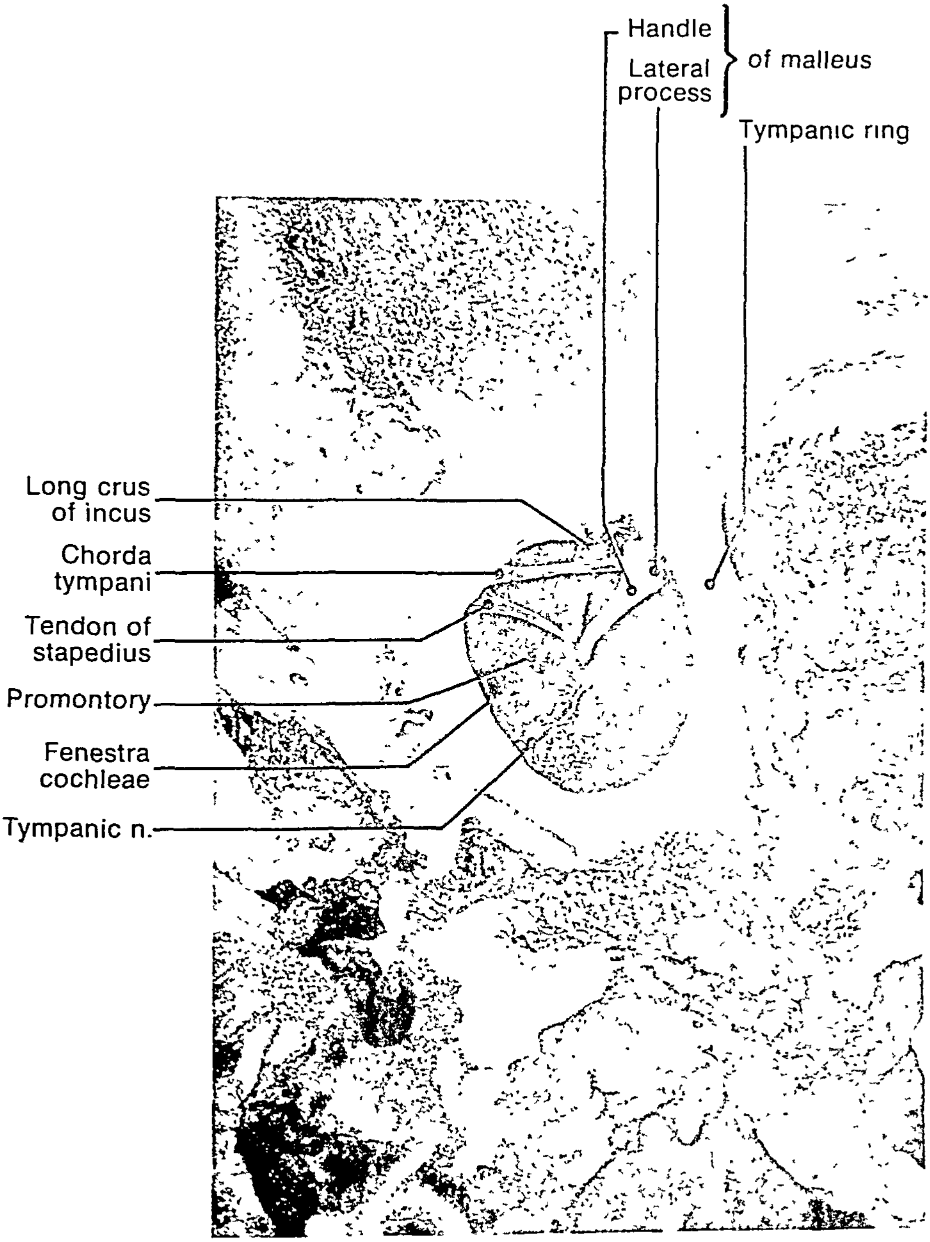


Figure 23.

Figure 24. AUDITORY OSSICLES *IN SITU*

After removal of the upper half of the tympanic ring in this newborn infant, the epitympanic recess has been widely opened. Two of the ossicles, the malleus and the incus, have been completely exposed from the lateral side, and the incudomallear joint between them is clearly visible. The tympanic nerve can be detected on the lower portion of the promontory. In front, some of the osseous part of the auditory tube has been exposed.

REFERENCES

Davies, D. V. A note on the articulations of the auditory ossicles and related structures. J. Lar. Otol., *62*:533–536, 1948.

Harty, M. Elastic tissue in the middle-ear cavity. J. Lar. Otol., *67*:723–729, 1953.

Harty, M. The joints of the middle ear. Z. mikrosk.-anat. Forsch., *71*:24–31, 1964.

Schneck, C. D., and Permut, S. R. The ligamentous and tendinous apparatus of the malleus. Anat. Rec., *160*:423, 1968.

Wolff, D., and Bellucci, R. J. The human ossicular ligaments. Ann. Otol. Rhinol. Lar., *65*:895–910, 1956.

FIGURE 24.

Figure 24.

Figure 25. INCUS *IN SITU*

Although the malleus has been removed in this newborn infant, the incus is maintained *in situ* by the incudostapedial joint. The head of the stapes is still within its articular capsule. Immediately medial to the head, the tendon of the stapedius is inserted on the neck of the stapes. The posterior crus is partially visible, as is also the base in the fenestra vestibuli. Above the fenestra vestibuli, the facial canal protrudes laterally into the tympanic cavity. In this view, the tympanic plexus on the promontory has been exposed to a greater extent. The osseous part of the auditory tube has also been better demonstrated.

REFERENCES

Alberti, P. W. R. M. The blood supply of the incudostapedial joint and the lenticular process. Laryngoscope, St Louis, *73*:605–628, 1963.

Hamberger, C.-A., and Wersäll, J. Vascular supply of the tympanic membrane and the ossicular chain. Acta oto-lar., Suppl. *188*:308–318, 1964.

Nager, G. T., and Nager, M. The arteries of the middle ear, with particular regard to the blood supply of the auditory ossicles. Ann. Otol. Rhinol. Lar., *62*:923–949, 1953.

FIGURE 25.

Figure 25.

Figure 26. STAPES *IN SITU*

The head of the stapes, which is the most prominent part of the bone seen in a lateral view, can be observed only when the incus has been disarticulated and removed. The insertion of the stapedius on the neck can be seen clearly adjacent to the head of the ossicle in this newborn infant. In addition, the base of the stapes within the fenestra vestibuli has been brought better into view, and only its posterior part is still masked by the prominent segment of the pyramidal eminence.

The prominence of the facial canal, above the fenestra vestibuli, has been completely exposed. The relief of the most anterior part of this prominence, however, is obscured slightly by the cochleariform process. Moreover, because more cancellous bone has been removed from the region above the facial prominence, a mass of compact bone containing the anterior semicircular canal has been exposed.

REFERENCES

Altmann, F., and Basek, M. The finer structure of the human stapes. Archs Otolar., *73*:507–512, 1961.

Dass, R., Grewal, B. S., and Thapar, S. P. Human stapes and its variations. J. Lar. Otol., *80*:11–25, 471–480, and 1023–1037, 1966.

FIGURE 26.

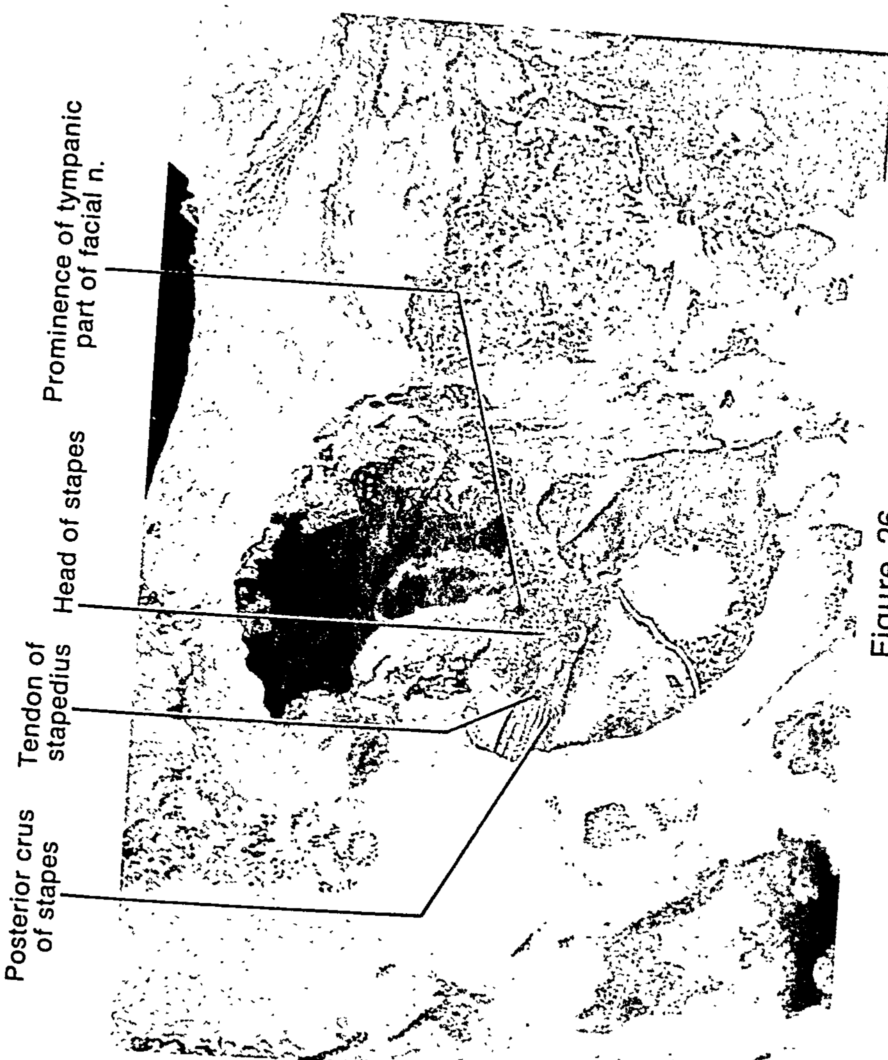


Figure 26.

Figure 27. AUDITORY OSSICLES, ARTICULATED

The precise relationships of the ossicles to each other are shown in this view, in which the ossicles of an adult have been re-assembled as accurately as possible. They are seen here from the lateral side, and most of the various features of the malleus (head, neck, anterior and lateral processes, handle), incus (body, short and long crura), and stapes (head, neck, anterior and posterior crura, base) can be observed.

REFERENCE

Galioto, G. B., and Marley, A. Structure of human auditory ossicles as shown by osteo-micropneumography and radiology. Acta oto-lar., *60*:347–359, 1965.

FIGURE 27.

Figure 27.

Figure 28. AUDITORY OSSICLES, DISARTICULATED

Two distinct zones are evident on the head of the malleus: articular and nonarticular. A groove demarcates these two zones. The articular surface extends onto the lateral, the medial, and (to a greater extent) the posterior surface of the head of the ossicle. In shape it resembles an 8.

The body of the incus is also partitioned by a shallow groove into articular and nonarticular parts. The articular part faces primarily anteriorly, although it also extends slightly onto the lateral and medial aspects of the ossicle. The nonarticular part completely surrounds the articular surface.

The head and neck of the stapes are better seen in a superior or an inferior view; the latter is shown here. In contrast, only a profile of the base of the ossicle is observed. The base is thicker at its periphery, and the central part may even be dehiscent in some instances.

REFERENCE

De Vincentiis, I., and Cimino, A. Rilievi morfologici, metrici e ponderali sugli ossicini dell' orecchio medio. Riv. Biol., *49:*181–204, 1957.

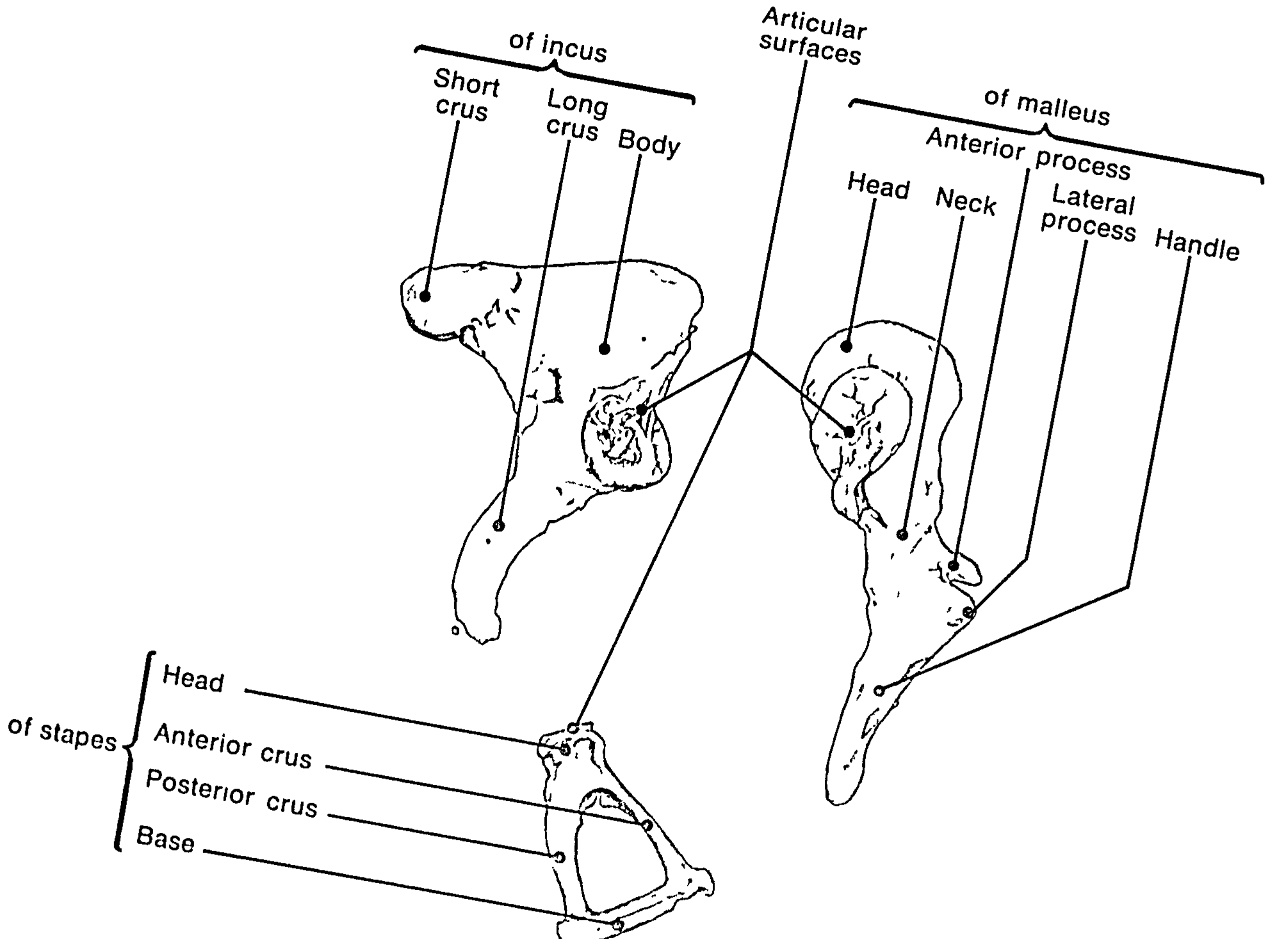


Figure 28.

FIGURE 28.

Figure 29. SEMICANAL FOR AUDITORY TUBE

In order to exhibit some further features of the anterior extension of the middle ear and yet still preserve the ossicles as points of topographical reference, another newborn specimen has been explored. The skull has been sectioned sagittally through the tegmen tympani and the tympanic cavity, immediately lateral to the ossicles, and the lateral segment has been removed. The cortical layer and the air cells of the mastoid process have been dissected away as far medially as the mastoid antrum. Anteriorly, the osseous part of the auditory tube has been opened widely from the lateral side. It is a forward prolongation of the tympanic cavity, and it may be regarded as a portion of the pneumatic area of the temporal bone.

The part of the tegmen that is adjacent to the uppermost portions of the malleus and incus is very thin, and forms the roof of the epitympanic recess. The ossicles have been retained *in situ*, and, deep to them, a portion of the tympanic plexus is seen on the promontory. On the medial wall of the opened auditory tube, just below the septum between the semicanals, a bluish area indicates the course of the internal carotid artery in the carotid canal. Although the roof of the tympanic cavity is smooth, the floor presents a very irregular surface adjacent to the promontory.

REFERENCES

Graves, G. O., and Edwards, L. F. The Eustachian tube. Archs Otolar., *39*:359–397, 1944.

Schwarzbart, A. A reappraisal of the clinical and morphological classification of the tympanic spaces and the Eustachian tube. Ann. Otol. Rhinol. Lar., *67*:241–245, 1958.

Terracol, J., Corone, A., and Guerrier, Y. *La trompe d'Eustache.* Masson, Paris, 1949.

FIGURE 29.

Figure 29.

Figure 30. TENSOR TYMPANI

Removal of more bone from the lateral side of the middle ear in this newborn infant has exposed almost the entire lateral aspect of the tensor tympani. The muscle arises chiefly from the cartilaginous part of the auditory tube but also (represented here by a white zone) from the inside of the semicanal in which the muscle lies. The muscular belly proceeds directly posteriorly through the semicanal, and its tendon turns laterally through a right angle (Fig. 47) around the previously removed cochleariform process. As can be seen here, the tensor has a short course within the tympanic cavity before it inserts on the medial side of the handle of the malleus. The muscle is supplied by a branch of the mandibular nerve. A bony septum is evident between the semicanal for the tensor tympani and that for the auditory tube. More of the course of the internal carotid artery (bluish zone) can be seen on the medial wall of the auditory tube.

REFERENCES

Girardet, R. Contribution à l'étude de l'innervation du muscle du marteau. Archs Anat. Histol. Embryol., *43:*121–164, 1960.

Lawrence, M. The double innervation of the tensor tympani. Ann. Otol. Rhinol. Lar., *71:*705–718, 1962.

Winckler, G. L'équipement nerveux du muscle tenseur du voile du palais. Archs Anat. Histol. Embryol., *47:*313–316, 1964.

FIGURE 30.

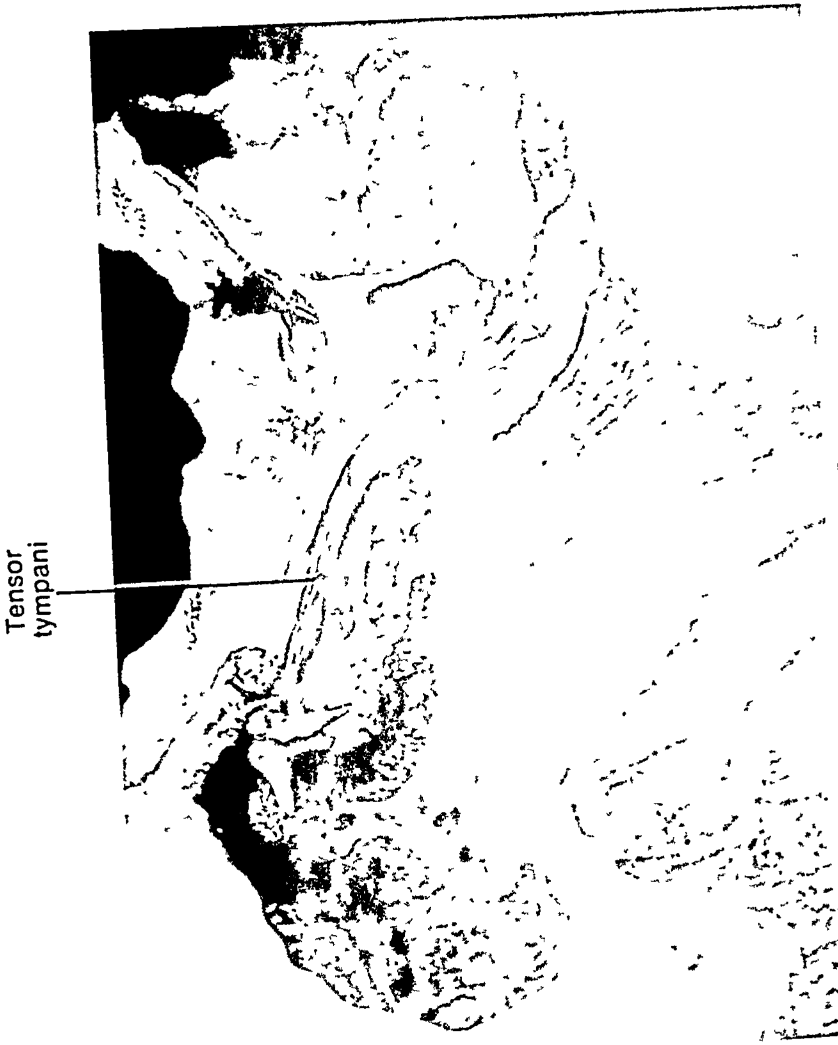


Figure 30

Figure 32. FENESTRA COCHLEAE AND FENESTRA VESTIBULI

The incus has been removed in this newborn infant, and most of the promontory can be seen. In the subepithelial layer of the promontory, the components of the tympanic plexus are visible. The fenestra cochleae has been exposed widely on the posterior surface of the promontory. The stapes, to which the tendon of the stapedius is still attached, remains anchored in the fenestra vestibuli. Above this fenestra, the tympanic part of the facial canal protrudes markedly into the tympanic cavity. Superiorly, because the cancellous bone has been partially chipped away, the shell of compact bone containing the semicircular canals is coming into view.

FIGURE 32.

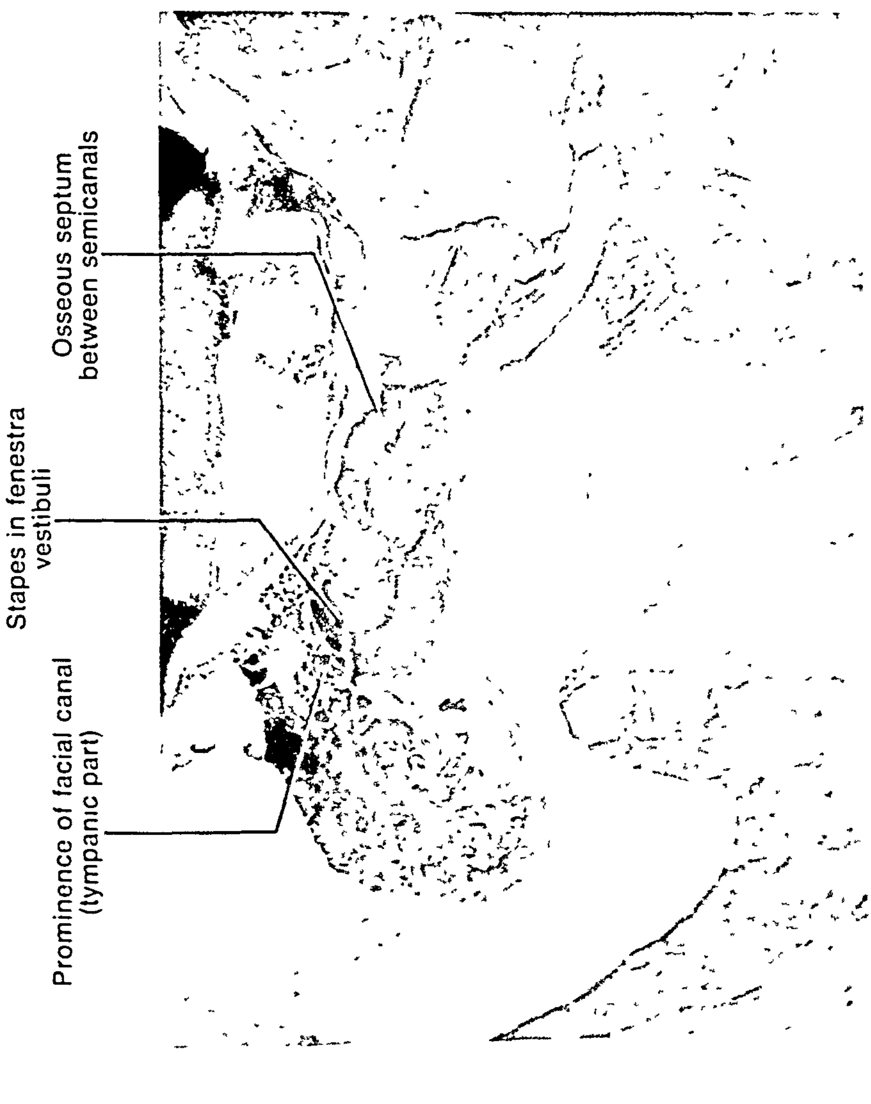


Figure 32.

Figure 33. PROMONTORY AND OSSEOUS PART OF AUDITORY TUBE

Ready identification of the auditory tube in an intact, dried skull is frequently hindered by the irregular surface on which it opens and by the presence of various bony processes which may obscure the orifice. Moreover, the course of the tube within the temporal bone, as well as the relationship of the tube to the various parts of the middle ear, is also difficult to appreciate in an intact skull. The present preparation is introduced to clarify these matters.

All portions of the temporal bone lateral to the osseous part of the auditory tube were removed from a dried skull with the aid of a dental drill. By this procedure, the most anterior part of the middle ear has been exposed. It becomes evident that the floor of the tympanic cavity proper continues anteriorly and medially as the floor of the auditory tube as far forward as the osseocartilaginous junction. From this point, the cartilaginous part of the auditory tube continues the connection between the tympanic cavity and the nasopharynx.

Within the tympanic cavity, almost the entire promontory has been exposed. The fenestra vestibuli and the fenestra cochleae are found behind it.

REFERENCES

Graves, G. O., and Edwards, L. F. The Eustachian tube. Archs Otolar., *39*:359–397, 1944.

Schwarzbart, A. A reappraisal of the clinical and morphological classification of the tympanic spaces and the Eustachian tube. Ann. Otol. Rhinol. Lar., *67*:241–245, 1958.

Terracol, J., Corone, A., and Guerrier, Y. *La trompe d'Eustache.* Masson, Paris, 1949.

FIGURE 33.

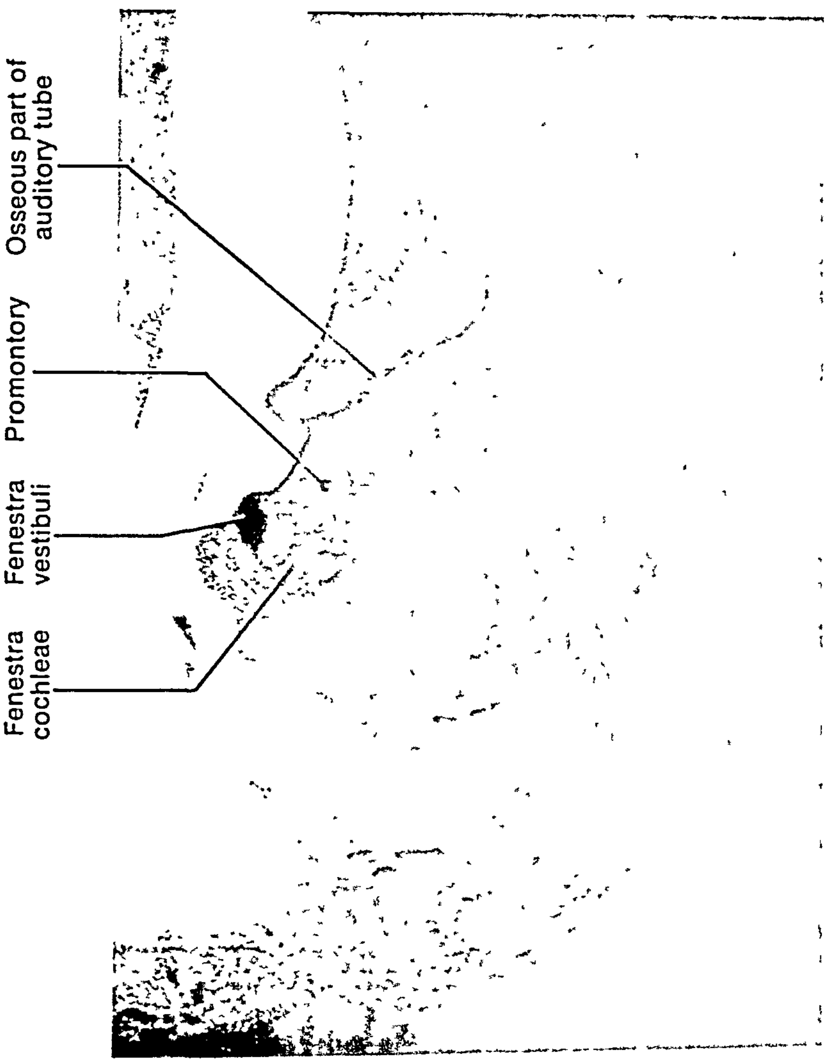

Osseous part of auditory tube
Promontory
Fenestra vestibuli
Fenestra cochleae

Figure 34. FACIAL NERVE IN FACIAL CANAL

The facial canal has been opened throughout its entire course, thereby exposing the facial nerve. The three parts of the nerve previously referred to (Fig. 11) can be seen clearly.

(1) The labyrinthine part extends laterally and slightly anteriorly from the fundus of the internal acoustic meatus to where the nerve enlarges to form the geniculate ganglion, which is the most prominent part of the facial nerve anteriorly. The greater petrosal nerve arises from the ganglion, and, after pursuing a complicated course through the middle cranial fossa, the foramen lacerum, and the pterygoid canal, brings preganglionic, parasympathetic fibers to the pterygopalatine ganglion.

(2) The tympanic part proceeds directly posteriorly from the geniculate ganglion, and is closely related to the lateral semicircular canal above and to the fenestra vestibuli below. This portion of the facial nerve is separated from the tympanic cavity by only a thin, bony lamina.

(3) The mastoid part of the nerve descends to the stylomastoid foramen, through which the facial nerve leaves the skull.

The lesser petrosal nerve arises from the reunion of some of the branches of the tympanic plexus on the promontory. It passes deep to the tensor tympani and then pierces the roof of the tympanic cavity. During this part of its course, the lesser petrosal is joined by the communicating branch of the facial nerve.

REFERENCES

Donaldson, J. A., and Anson, B. J. The triple "S" triangle. A topographical guide to the facial nerve in temporal bone surgery. Ann. Otol. Rhinol. Lar., *74*:59–62, 1965.

Hall, G. M., Pulec, J. L., and Rhoton, A. L. Geniculate ganglion anatomy for the otologist. Archs Otolar., *90*:568–571, 1969.

Vidić, B. The origin and the course of the communicating branch of the facial nerve to the lesser petrosal nerve in man. Anat. Rec., *162*:511–515, 1968.

FIGURE 34.

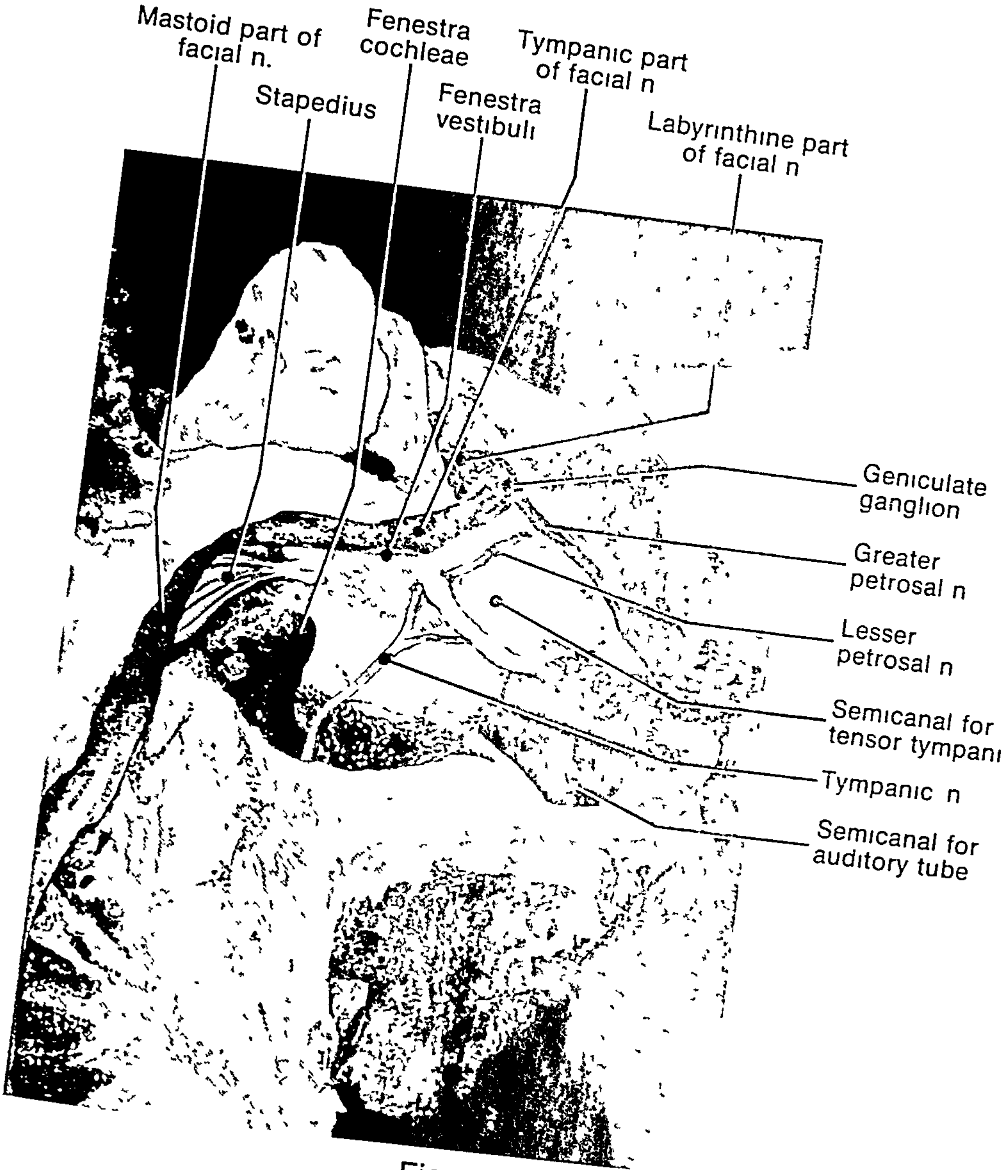


Figure 34.

Figure 35. BASAL TURN OF COCHLEA

After the ossicles and all the soft tissues had been extracted from the middle ear, the promontory was perforated by a dental drill, thereby exposing the basal turn of the cochlea. The main object of this preparation is to demonstrate the relationship between the perilymphatic space of the cochlea and the tympanic cavity; actually these are separated from each other by only the bone of the promontory. In addition, the manner in which the cochlea extends clockwise (in the right ear) around the modiolus becomes clearer. The upper part of the middle coil has been opened from above. Part of the modiolus is also evident.

Behind the cochlea, two of the semicircular canals, the anterior and the lateral, have been opened from the superior aspect and from the lateral side, respectively. The fenestra vestibuli faces the part of the vestibule that is close to where the anterior and lateral semicircular ducts converge toward the utricle.

FIGURE 35.

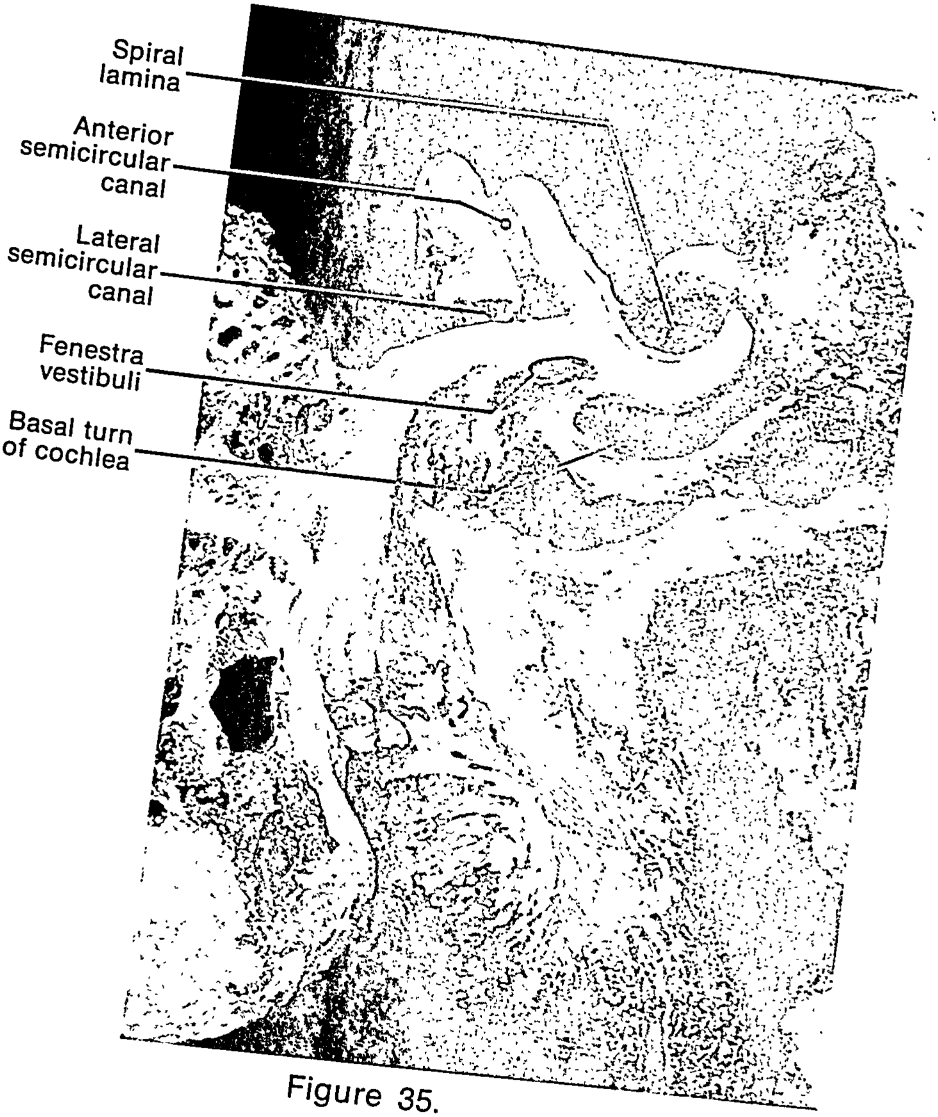


Figure 35.

Figure 36. MODEL OF FETAL MEMBRANOUS LABYRINTH

This lateral view of a wax-plate reconstruction shows the membranous labyrinth (in yellow on the slide) of a human fetus aged less than four months (85 mm C.R.). The manner in which the developing perilymphatic space (in green) is applied first to the lateral aspect of the membranous labyrinth is well indicated. Although the scala tympani does not yet communicate with the scala vestibuli (the helicotrema has not formed), the scala vestibuli is continuous with the beginning vestibule, which, in turn, is just extending onto the utricle and the lateral semicircular duct. Further extension (arrows) of the perilymphatic space along the semicircular ducts will occur later. In this manner, the membranous labyrinth will become largely surrounded by the perilymphatic space. The stapes and the endolymphatic sac are shown in blue. The supporting rod for the model has been omitted in the drawing. Additional views of this and other specimens during development may be found in Streeter's article.

The membranous labyrinth develops from the otic vesicle, the primordium of which may be recognized at three weeks after fertilization. By the end of the embryonic period proper, *i.e.*, at eight weeks after fertilization, the cochlear duct already shows more than two turns.

REFERENCES

O'Rahilly, R. The early development of the otic vesicle in staged human embryos. J. Embryol. exp. Morph., *11*:741–755, 1963.

Streeter, G. L. The histogenesis and growth of the otic capsule and its contained periotic tissue-spaces in the human embryo. Contr. Embryol., *7*:5–54, 1918.

FIGURE 36.

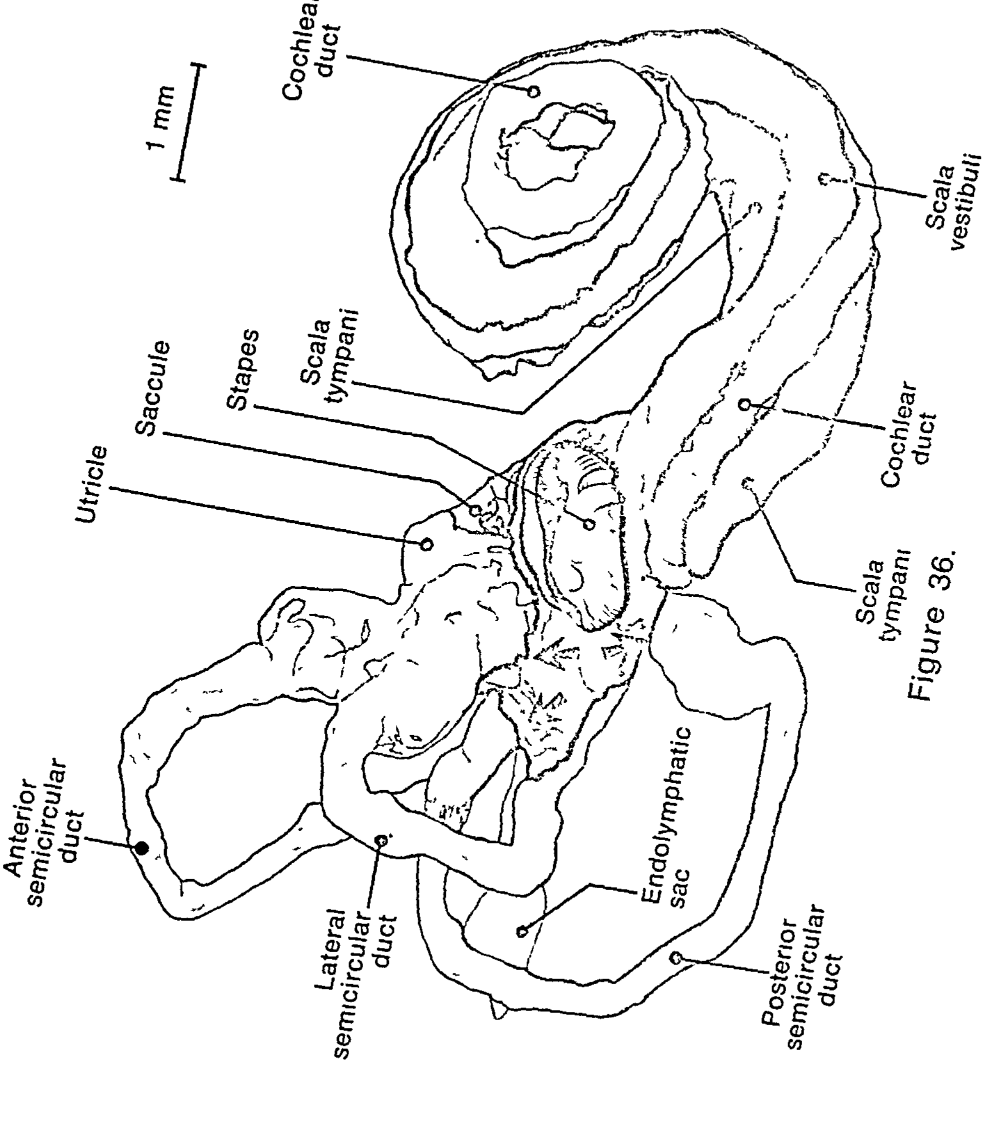


Figure 36.

Figure 37. POSTEROLATERAL VIEW OF OSSEOUS LABYRINTH

The internal ear consists of a complex series of spaces, the membranous labyrinth, filled with endolymph and lodged within a similarly arranged cavity, the bony labyrinth, which is filled with perilymph.

In this preparation, all the components of the osseous labyrinth have been sculptured from the bone, without, however, having been perforated. In other words, what is termed the "otic capsule" has been exposed. This view, primarily from the lateral side and less so from behind, displays the entire extent of the semicircular canals. The medial ends of the anterior and posterior canals unite with each other, as do the lateral ends of the anterior and lateral canals. The fenestra vestibuli is seen to be situated near that part of the vestibule in which the anterior and lateral canals open by a common passage.

The promontory is intact and is separated from the rest of the medial wall of the tympanic cavity. The middle and apical coils are visible on the superior aspect of the cochlea.

REFERENCES

Anson, B. J., Harper, D. G., and Winch, T. R. The vestibular system. Anatomic considerations. Archs Otolar., *85:*497–514, 1967.

Anson, B. J., Warpeha, R. L., Donaldson, J. A., and Rensink, M. J. The developmental and adult anatomy of the membranous and osseous labyrinth and of the otic capsule. Otolar. Clin. N. Am., *1:*273–304, 1968.

Axelsson, A. The vascular anatomy of the cochlea in the guinea pig and in man. Acta oto-lar., Suppl. *243:*1–134, 1968.

Gussen, R. Articular and internal remodeling in the human otic capsule. Am. J. Anat., *122:*397–417, 1968.

Gussen, R. The labyrinthine capsule: normal structure and pathogenesis of otosclerosis. Acta oto-lar., Suppl. *235:*1–55, 1968.

Zechner, G., and Altmann, F. Ground substance of the otic capsule. Histochemical studies. Archs Otolar., *90:*418–428, 1969.

FIGURE 37.

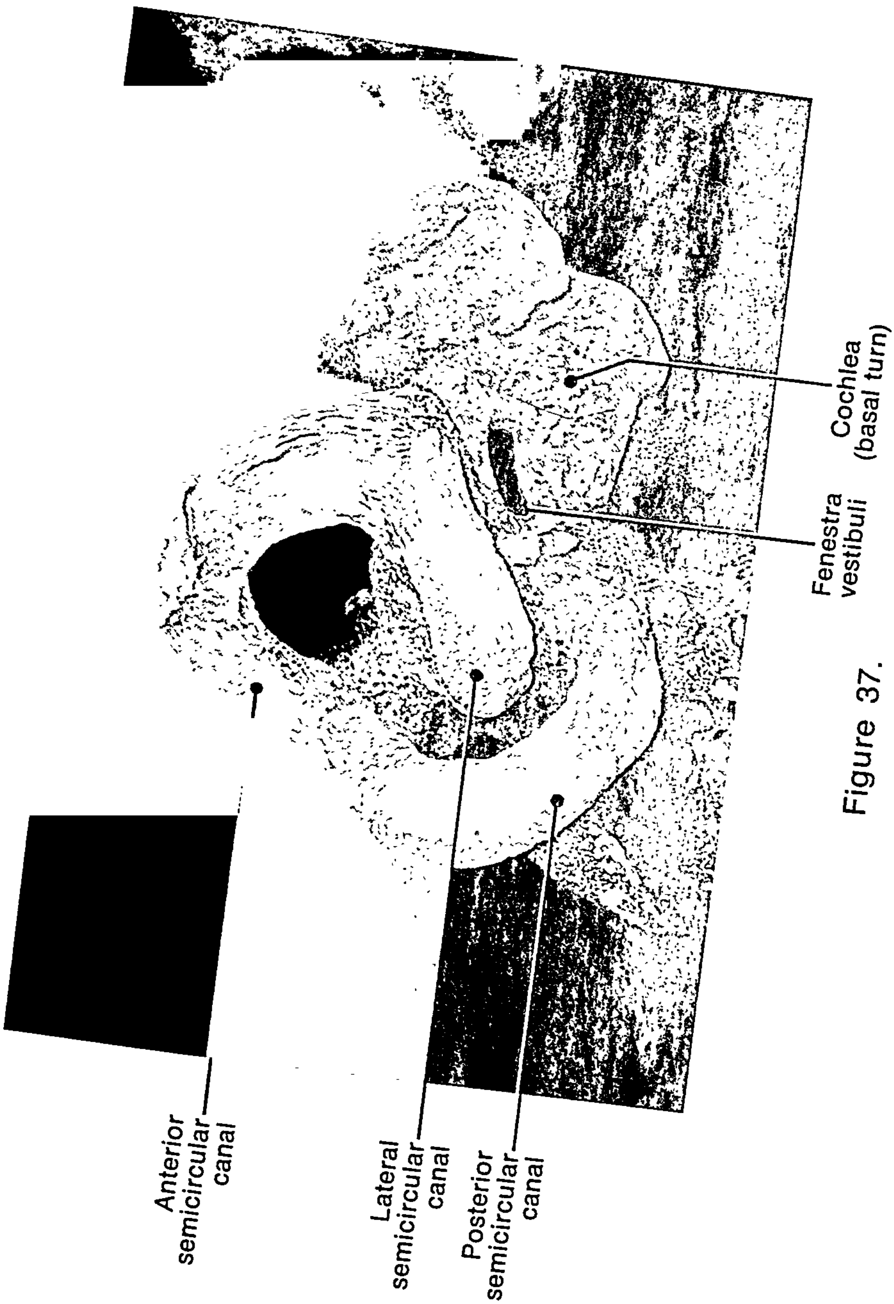


Figure 37.

Figure 38. SUPERIOR VIEW OF SEMICIRCULAR CANALS

Superior views of the ear, although more of anatomical than of surgical interest, make possible a better comprehension of the relationship between the components of the labyrinth and the contents of the internal acoustic meatus. Furthermore, superior views are of assistance in appreciating the depths of various structures from the surface.

The upper halves of the semicircular canals have been removed and the three canals are demonstrated from above. In front of them, the facial area of the fundus has been opened and the facial nerve removed. The vestibular and cochlear divisions of the eighth cranial nerve are seen intact in the internal acoustic meatus. More anteriorly, the untouched part of the petrous temporal contains the entire cochlea. The internal carotid artery, shown in the upper part of the illustration, is seen as it enters the cranial cavity in the immediate vicinity of the cochlea. The mastoid cells, the antrum, and the tympanic cavity are partially exposed lateral to the inner ear.

REFERENCES

Amjad, A H, Scheer, A A, and Rosenthal, J Human internal auditory canal Archs Otolar, *89* 709–714, 1969

Hansen, C C Vascular anatomy of the human temporal bone Ann Otol Rhinol Lar, *79* 269–273, 1970

Mazzoni, A Internal auditory canal Arterial relations at the porus acusticus Ann Otol Rhinol Lar, *78* 797–814, 1969

FIGURE 38.

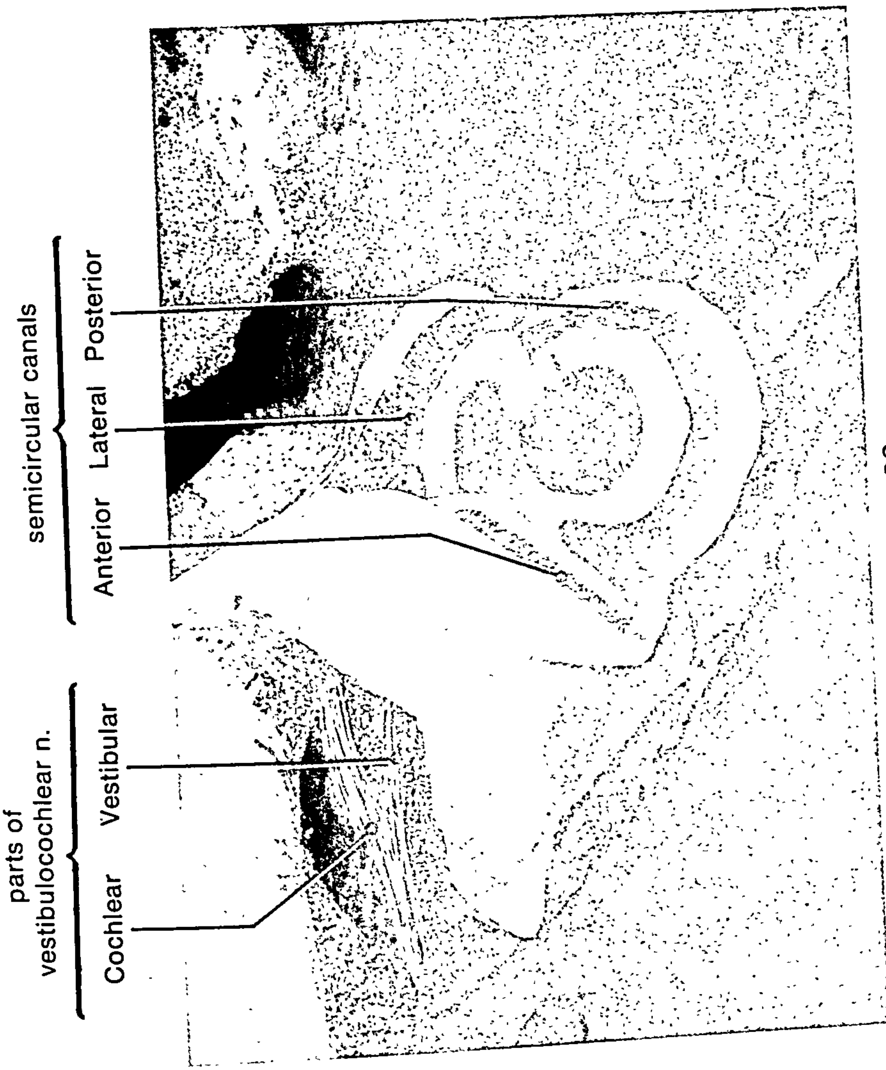


Figure 38.

Figure 39. SUPERIOR VIEW OF COCHLEA

In this close view of the bony labyrinth, the openings of the anterior and lateral semicircular canals are shown in the lower right-hand corner. Two distinct divisions of the vestibulocochlear nerve extend along the floor of the internal acoustic meatus and finally traverse their appropriate openings to gain the vestibule and the cochlea, respectively. The compact bony shell of the cochlea has been dissected out of the petrous temporal, and the upper half of each coil has been removed. Within the cochlea, the central pillar, or modiolus, is exposed; it extends almost directly anteriorly. The osseous spiral lamina which arises from the modiolus extends toward the periphery of the cochlea and forms a partition (completed in the intact state by the basilar membrane) between the scala vestibuli and the scala tympani.

REFERENCES

Anson, B. J., Winch, T. R., Warpeha, R. L., and Donaldson, J. A. The blood supply of the otic capsule of the human ear with special reference to that of the cochlea. Ann. Otol. Rhinol. Lar., 75:921–944, 1966.

Platzer, W. Über die Lage und Stellung der Laminae spirales in der basalen Schneckenwindung. Z. Anat. EntwGesch., *120*:372–378, 1958.

Shute, C. C. D. The anatomy of the eighth cranial nerve in man. Proc. R. Soc. Med., *44*:1013–1018, 1951.

FIGURE 39.

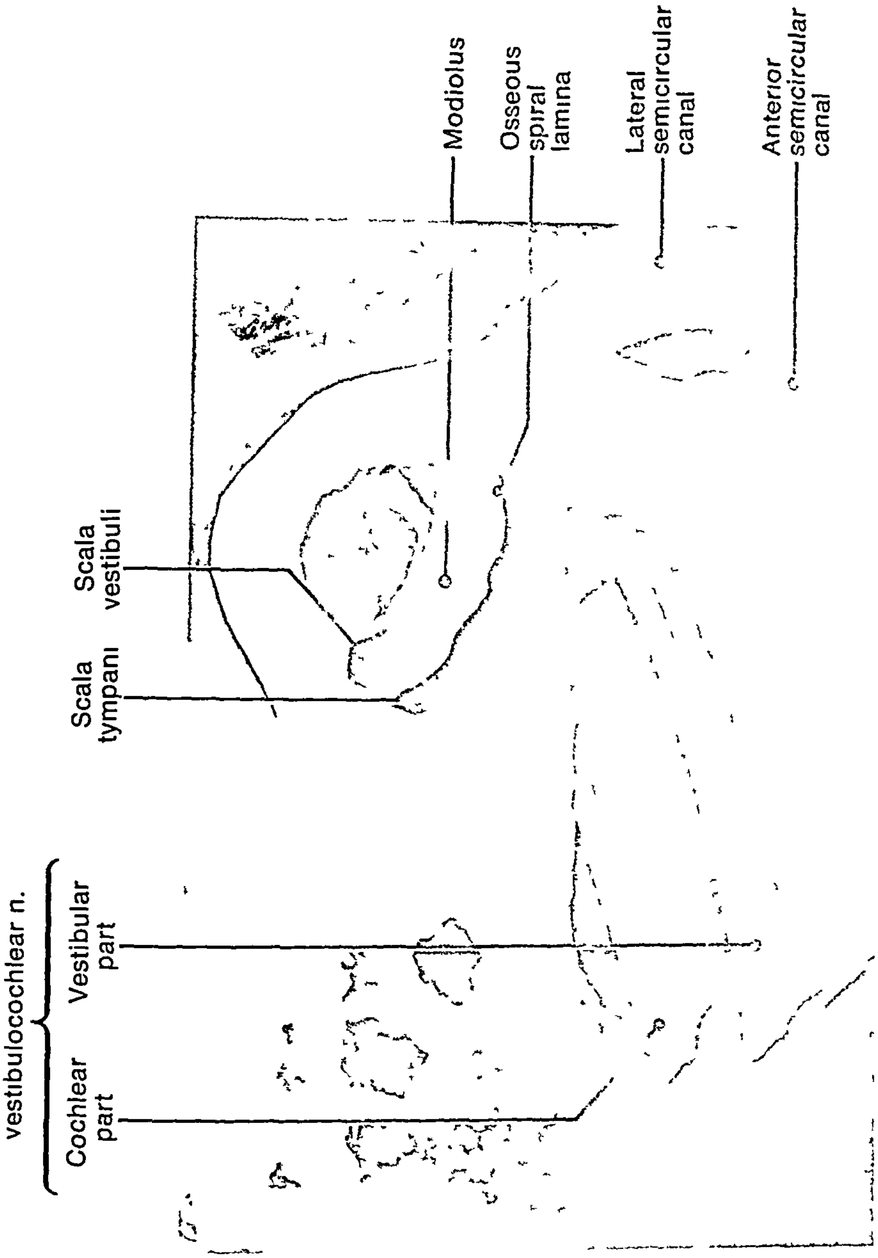


Figure 39.

Figure 40. SUPERIOR VIEW OF SEMICIRCULAR CANALS AND COCHLEA

This general view serves to summarize the two previous illustrations. The contents of the internal acoustic meatus have now been taken away. The semicircular canals, the internal acoustic meatus, and the cochlea have been exposed in their normal interrelationships. The floor of the meatus is formed of intact bone; hence the vestibule and the cochlea communicate with each other below the meatal floor. Beginning at the apex of the cochlea, the internal carotid artery has been exposed in the carotid canal.

REFERENCE

Hardy, M. The length of the organ of Corti in man. Am. J. Anat., *62*:291–311, 1938.

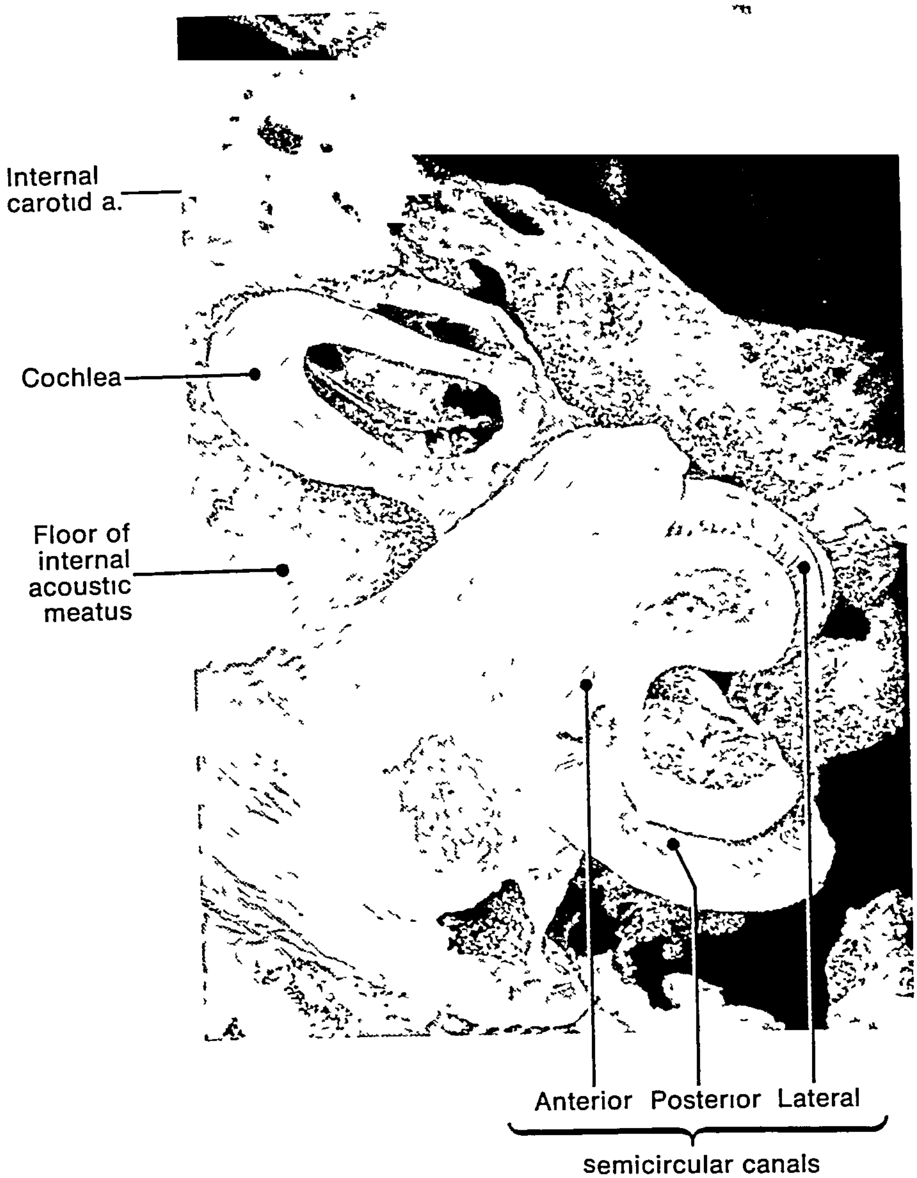

Internal carotid a.
Cochlea
Floor of internal acoustic meatus
Anterior
Posterior
Lateral
semicircular canals

Figure 40.

Figure 41. SUPERIOR VIEW OF SEMICIRCULAR CANALS AND MODIOLUS

While preserving the semicircular canals for topographical reference, the bony shell of the cochlea has been removed from all around the perilymphatic space. By this procedure the modiolus has been freed from the rest of the bony cochlea. Only the central part of the osseous spiral lamina, *i.e.*, the portion close to the modiolus, has been preserved here.

FIGURE 41.

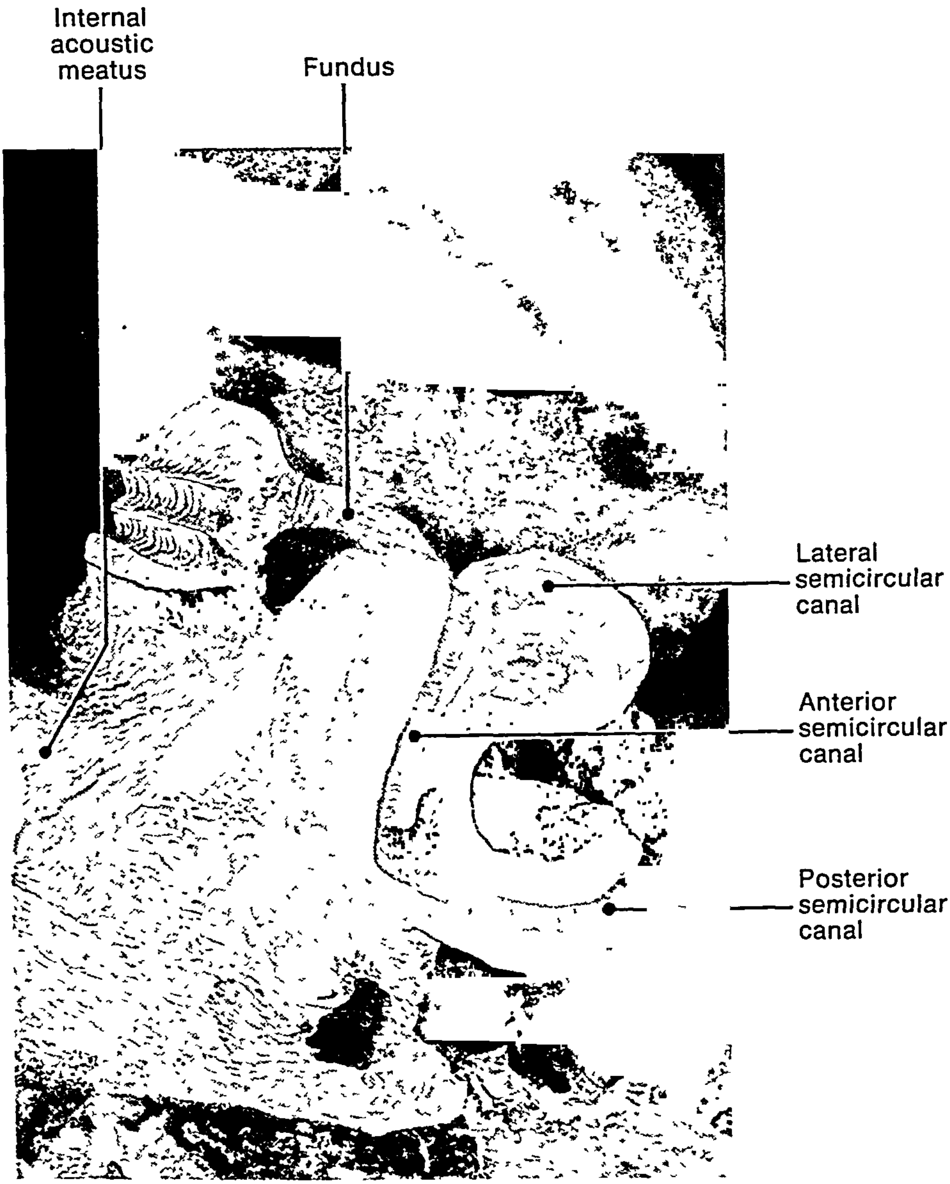


Figure 41.

Figure 43. SUPERIOR VIEW OF CHORDA TYMPANI AND INCUDOMALLEAR JOINT

The stapes, the stapedius, and the tensor tympani have been removed from this preparation, and the entire intratympanic course of the chorda tympani has been exposed. In front of the malleus, the anterior ligament having been removed, the chorda tympani has been dissected toward its exit from the tympanic cavity, namely, the petrotympanic fissure.

REFERENCE

Mark, H. Zur Anatomie der Falten und Bänder am Hammerkopf. Z. Anat. EntwGesch., *122:*114–120, 1960.

FIGURE 43.

Figure 43.

Figure 44. SUPERIOR VIEW OF OSSEOUS LABYRINTH

This preparation, which is shown from the posterolateral side in Figure 37, may be used to demonstrate the parts of the osseous labyrinth as seen from above. It can readily be appreciated that the planes of any two semicircular canals meet each other at almost a right angle. Only the middle and apical coils of the cochlea are evident in this view. The depression within the curve of the middle coil indicates the site of entry of the cochlear division of the eighth cranial nerve into the modiolus. The groove between the anterior semicircular canal and the cochlea is the lower half of that part of the fundus through which the facial nerve enters its own bony canal.

REFERENCE

Altmann, F. Malformations, anomalies, and vestigial structures of the inner ear. Archs Otolar., 57:591–602, 1953.

FIGURE 44.

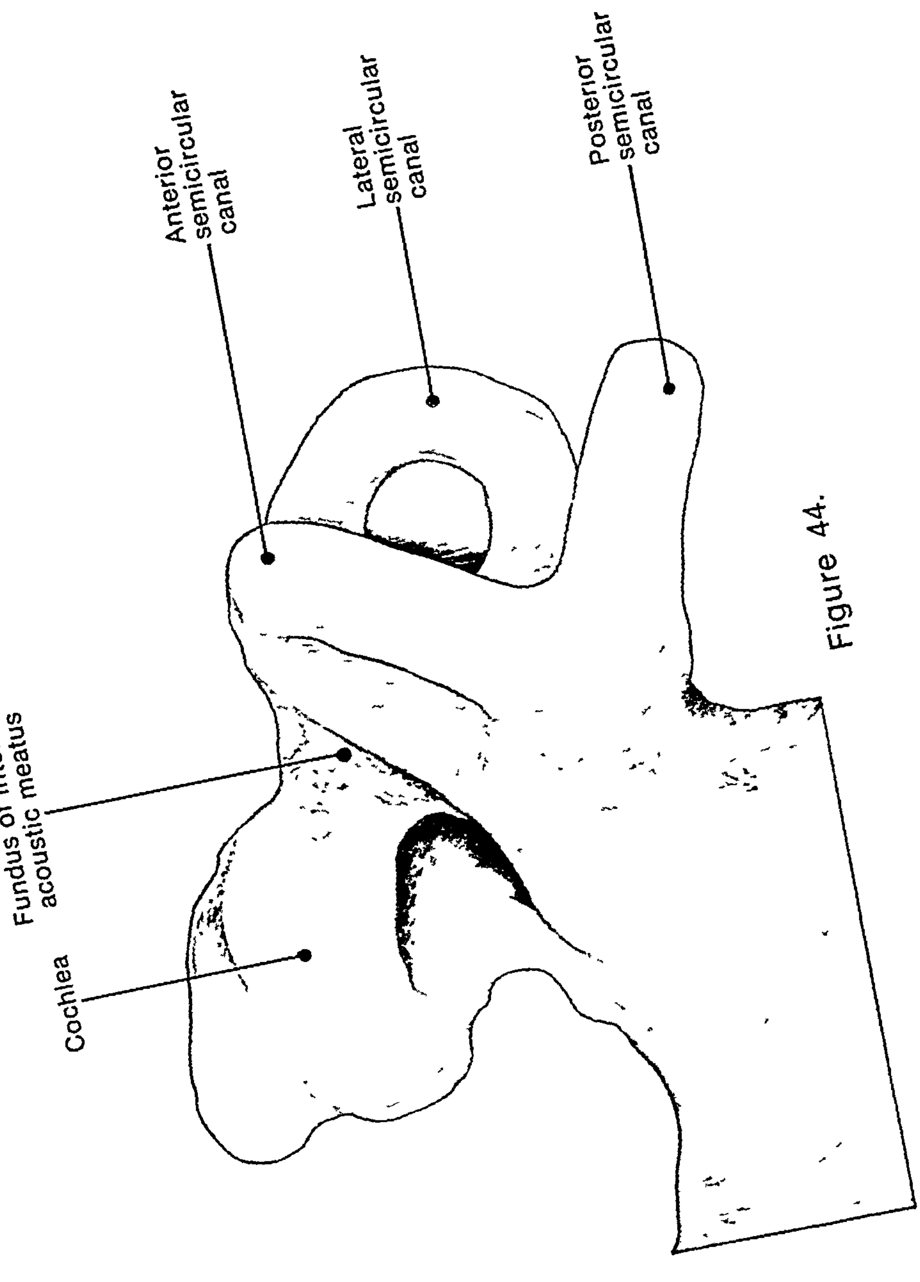
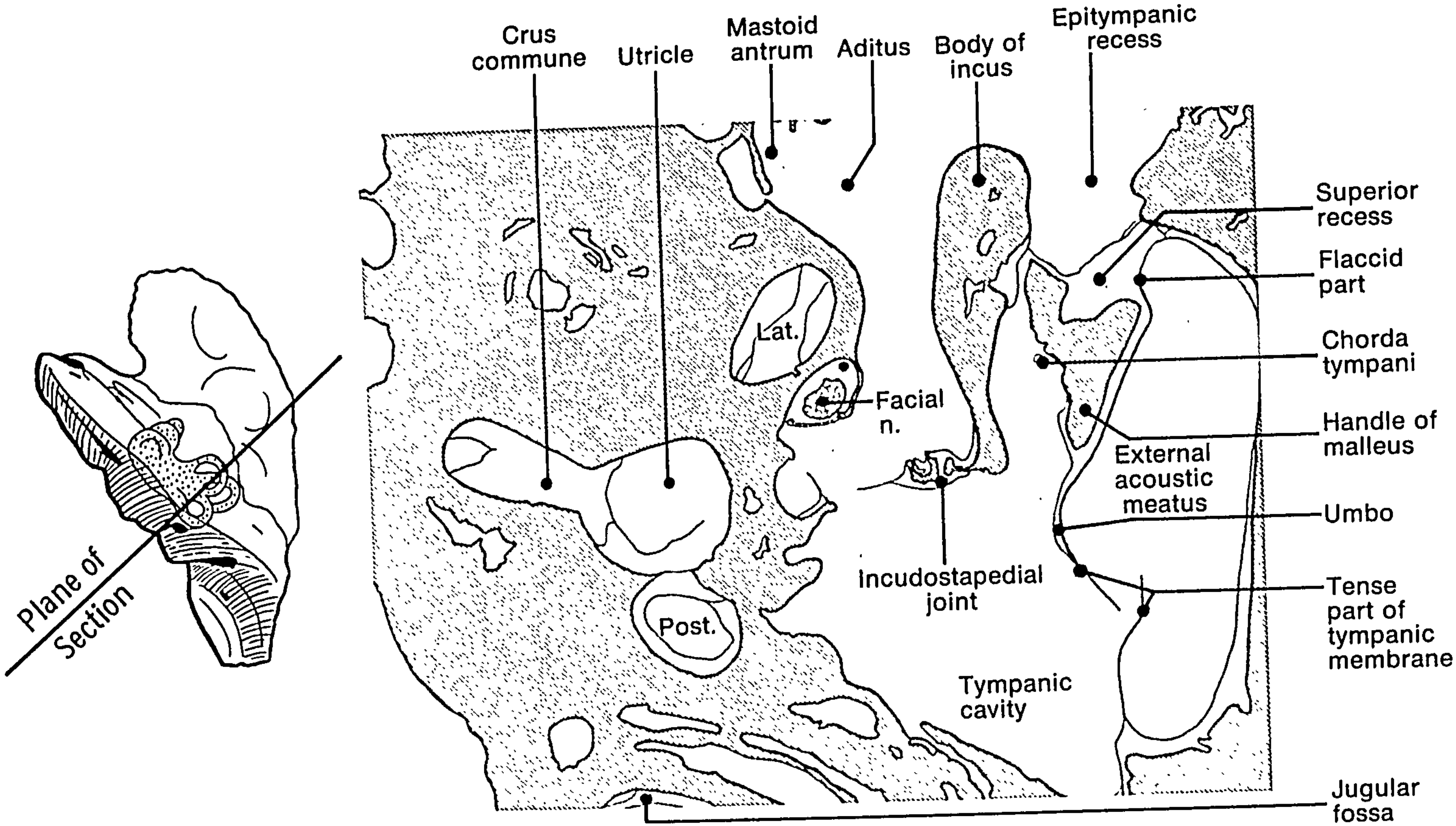


Figure 44.

Figure 45. VERTICAL SECTION THROUGH TYMPANIC MEMBRANE, AUDITORY OSSICLES, AND EPITYMPANIC RECESS

This vertical section, at a right angle to the longitudinal axis of the petrous temporal, passes through the semicircular canals, the tympanic cavity, and the external acoustic meatus (see diagram). The ossicles can be identified readily, and the aditus leading from the epitympanic recess to the antrum is evident. The facial nerve can be seen in cross-section on the medial wall of the tympanic cavity, just below the lateral semicircular canal. The flaccid and tense parts of the tympanic membrane can be distinguished, and the superior recess (described by Prussak) is discernible.

FIGURE 45.



Lat.: lateral semicircular canal
Post.: posterior semicircular canal

Figure 45.

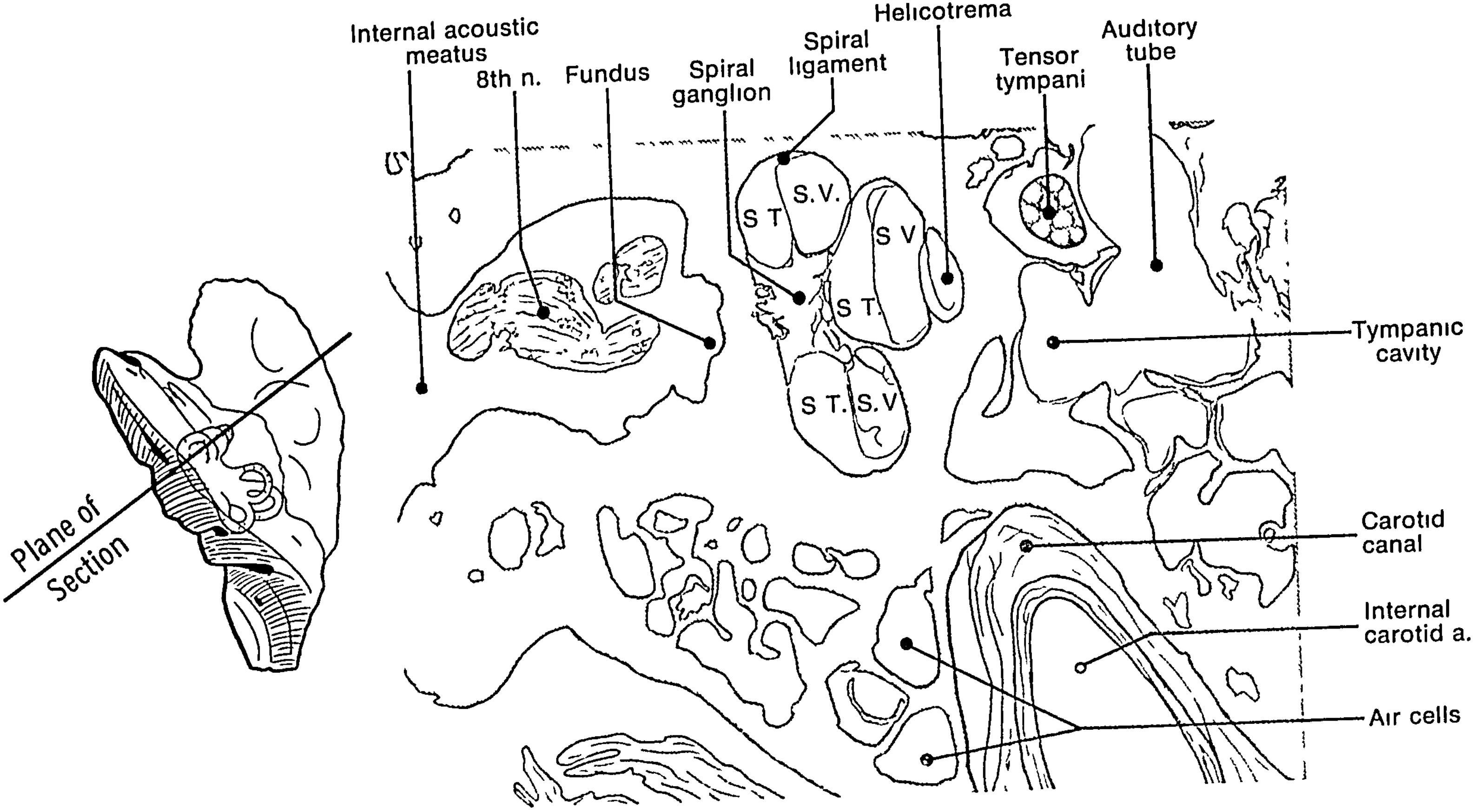
Figure 46. VERTICAL SECTION THROUGH COCHLEA AND INTERNAL ACOUSTIC MEATUS

This vertical section, at a right angle to the longitudinal axis of the petrous temporal, is anterior to that shown in the previous figure (see diagram). The section passes through the cochlea and the internal acoustic meatus. Portions of the auditory tube, the tympanic cavity, and the mastoid air cells are also visible. The tensor tympani can be seen in cross-section. The carotid canal is evident below.

REFERENCE

Wolff, D. The ganglion spirale cochleae. Am. J. Anat., *60*:55–77, 1936.

FIGURE 46.



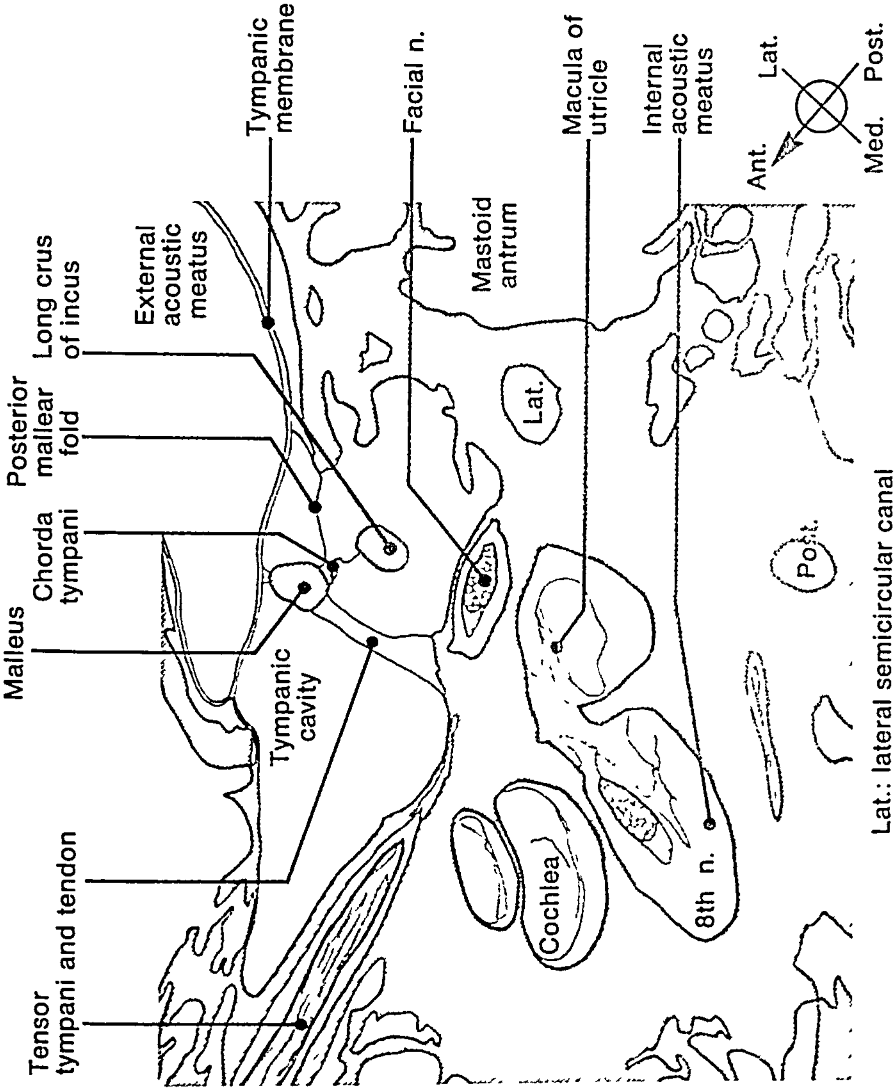
S T scala tympani
S.V.: scala vestibuli

Figure 46.

Figure 47. HORIZONTAL SECTION SHOWING TENSOR TYMPANI

This section, at a right angle to those shown in the previous two figures, passes through the external, middle, and internal ear. The course of the tensor tympani, its turn through a right angle, and its insertion on the malleus are particularly well shown. The chorda tympani can be identified in cross-section immediately posteromedial to the handle of the malleus.

FIGURE 47.



Lat.: lateral semicircular canal
Post.: posterior semicircular canal

Figure 47.

Figure 48. HORIZONTAL SECTION SHOWING STAPEDIUS

This section passes through the external, middle, and internal ear. Portions of the ossicles are visible, and the pyramidal eminence and the stapedius are well shown. The facial nerve can be seen in cross-section immediately posterolateral to the pyramidal eminence and adjacent to the lateral semicircular canal.

The endolymphatic duct arises from the junction of the utricular and saccular ducts (or directly from the saccule, depending on terminology), is transmitted by the aqueduct of the vestibule, and ends in the endolymphatic sac, under cover of the dura on the posterior surface of the petrous temporal.

REFERENCES

Anson, B. J. Endolymphatic hydrops. Anatomic aspects. Archs Otolar., *89*:96–110, 1969.

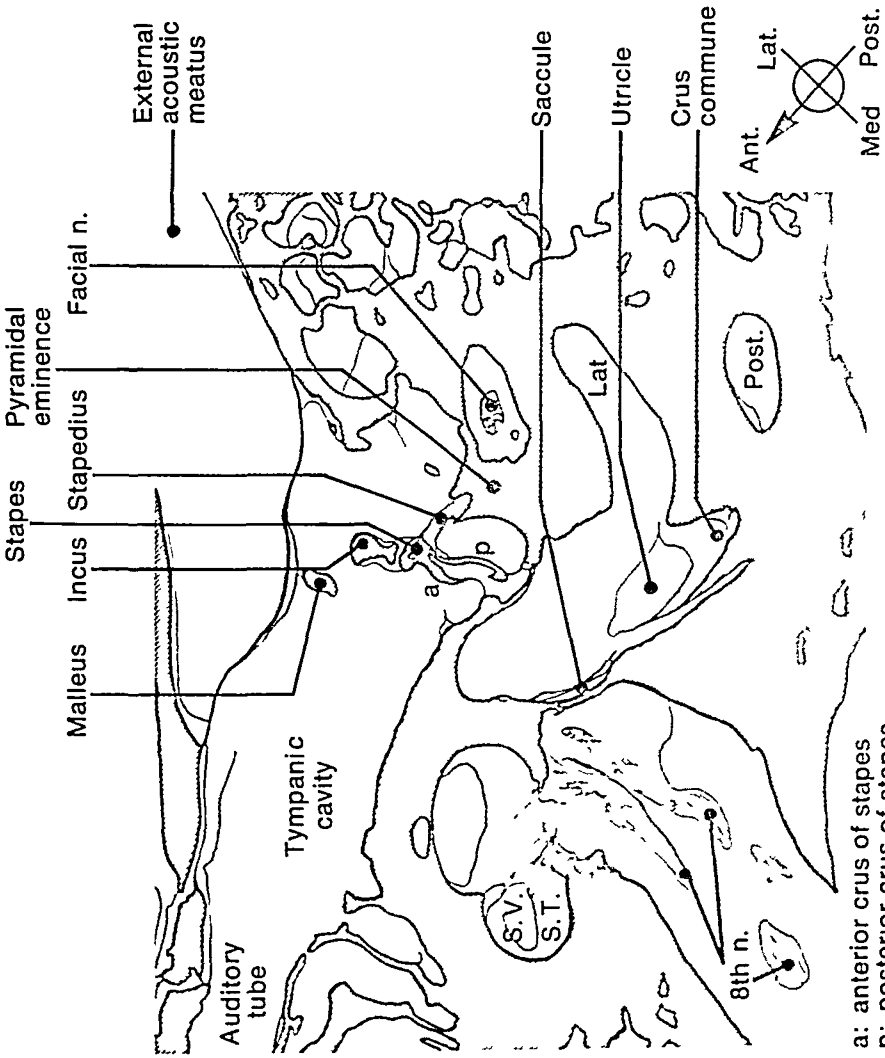
Anson, B. J. The endolymphatic and perilymphatic aqueducts of the human ear. Acta oto-lar., *59*:140–153, 1965.

Anson, B. J., Donaldson, J. A., Warpeha, R. L., and Winch, T. R. A critical appraisal of the anatomy of the perilymphatic system in man. Laryngoscope, St Louis, *74*:945–966, 1964.

Anson, B. J., Donaldson, J. A., Warpeha, R. L., and Winch, T. R. Surgical anatomy of the endolymphatic sac and perilymphatic duct. Laryngoscope, St Louis, *74*:480–497, 1964.

Palva, T., and Dammert, K. Human cochlear aqueduct. Acta oto-lar., Suppl. *246*:1–58, 1969.

FIGURE 48.



a: anterior crus of stapes
p: posterior crus of stapes

S T scala tympani
S V scala vestibuli

Lat lateral semicircular canal
Post posterior semicircular canal

Figure 48.

Figure 49. HORIZONTAL SECTION SHOWING SCALAE AND HELICOTREMA

This section passes through the cochlea and the internal acoustic meatus. The helicotrema is evident, and this slightly higher magnification shows the scalae to better advantage.

The relationships between the osseous and membranous labyrinths are well shown, for example, in the vestibule. The membranous labyrinth (*e.g.*, the utricle and the saccule) contains endolymph, whereas the bony labyrinth contains perilymph. The perilymphatic duct, or aqueduct of the cochlea (not shown here), which is situated in a bony channel (the cochlear canaliculus, although terminologies differ), is frequently stated to connect the scala tympani with the subarachnoid space.

REFERENCES

Anson, B. J. Endolymphatic hydrops. Anatomic aspects. Archs Otolar., *89:*96–110, 1969.

Anson, B. J. The endolymphatic and perilymphatic aqueducts of the human ear. Acta oto-lar., *59:*140–153, 1965.

Anson, B. J., Donaldson, J. A., Warpeha, R. L., and Winch, T. R. A critical appraisal of the anatomy of the perilymphatic system in man. Laryngoscope, St Louis, *74:*945–966, 1964.

Anson, B. J., Donaldson, J. A., Warpeha, R. L., and Winch, T. R. Surgical anatomy of the endolymphatic sac and perilymphatic duct. Laryngoscope, St Louis, *74:*480–497, 1964.

Palva, T., and Dammert, K. Human cochlear aqueduct. Acta oto-lar., Suppl. *246:*1–58, 1969.

FIGURE 49.

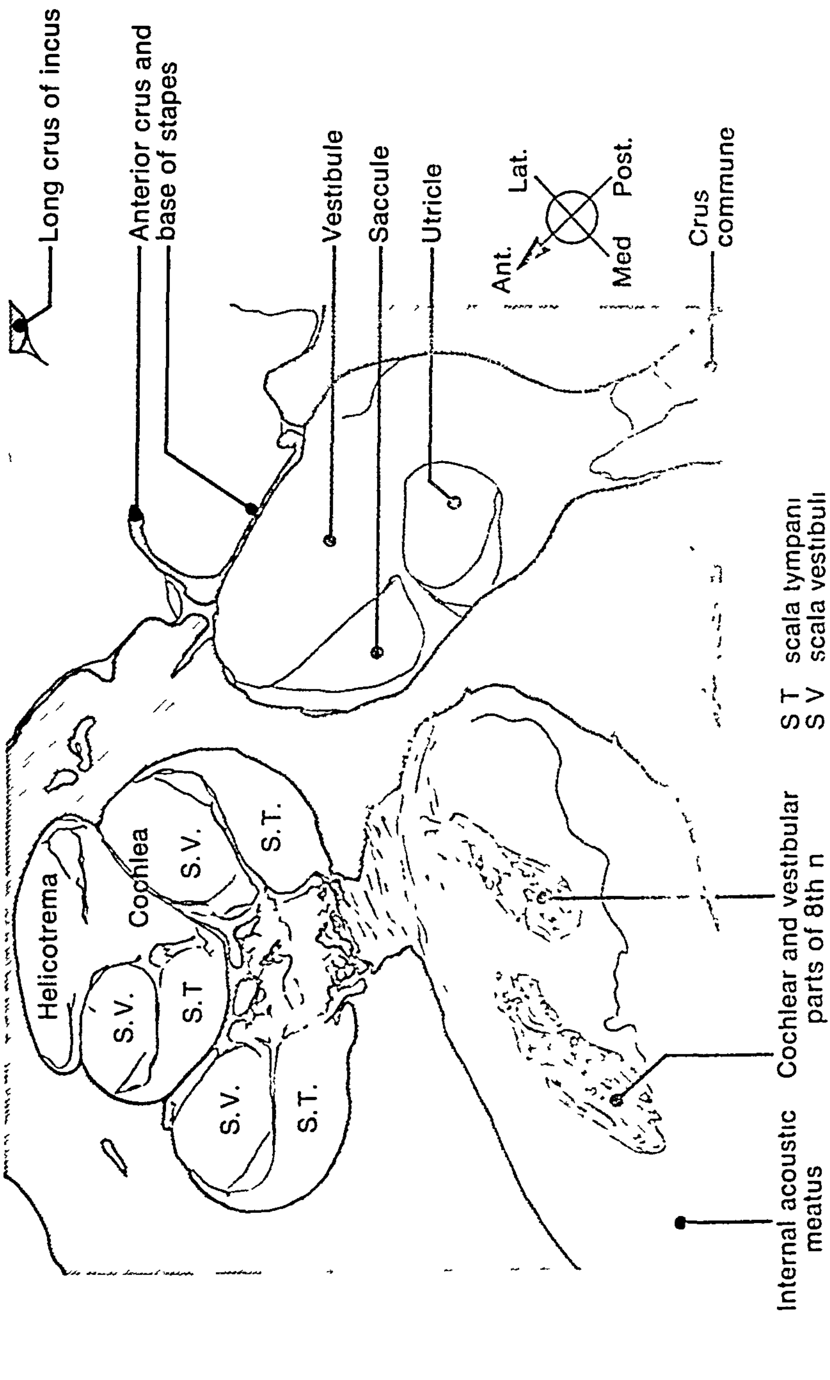
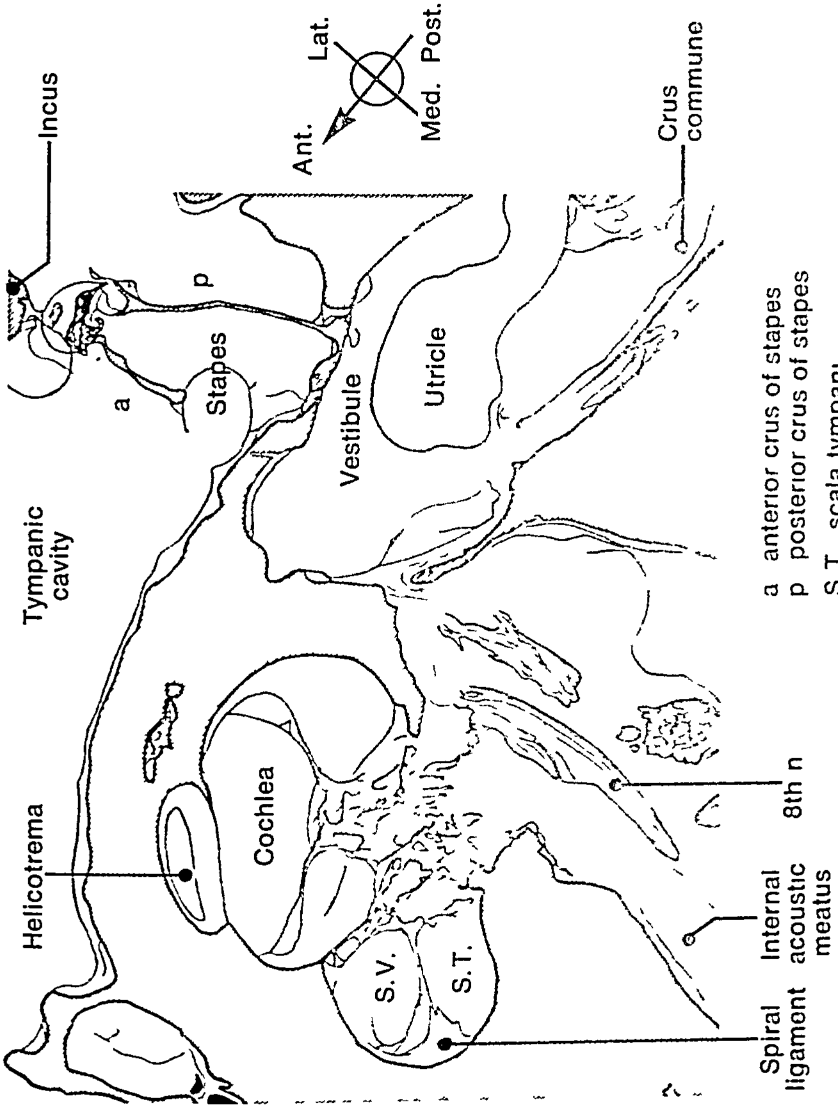


Figure 49.

Figure 50. HORIZONTAL SECTION SHOWING STAPES AND INCUDOSTAPEDIAL JOINT

This section passes through the cochlea, the helicotrema, and the internal acoustic meatus. The region of the incudostapedial joint is discernible, and the anterior and posterior crura of the stapes are evident.

FIGURE 50.



a anterior crus of stapes
p posterior crus of stapes

S T scala tympani
S V scala vestibuli

Figure 50.

GLOSSARY OF EPONYMOUS TERMS

Wherever possible, eponyms and other unofficial terms should be avoided and the *Nomina anatomica* employed. For reference purposes, the following list provides the eponyms most frequently found in accounts of the macroscopic structure of the ear. *Some general references of historical interest are appended.*

Corti, ganglion of: spiral ganglion of vestibulocochlear nerve

Corti, organ of: spiral organ resting on basilar lamina of cochlea. Alfonso Corti (1822–1888), born in Sardinia, described the mammalian ear in 1851.

Darwin's tubercle: a small, occasional, downward projection of the helix. Charles Darwin (1809–1882), English naturalist, had his attention drawn to the tubercle by Thomas Woolner (1825–1892), English sculptor.

Eustachian tube: auditory tube (strictly speaking, its cartilaginous part). Bartolomeo Eustachi (1513?–1574) was Professor of Anatomy in Rome. The existence of a pharyngotympanic communication was known to anatomists before the Christian era.

Fallopius, aqueduct of: facial canal. Gabriele Falloppio (1523–1563?) was Professor of Anatomy and Surgery in Padua.

Folian process: anterior process of malleus. Cecilio Folli, or Folius (1615–1660), was Professor of Anatomy in Venice.

Glaserian fissure: petrotympanic fissure. Johann Heinrich Glaser (1629–1675) was Professor of Anatomy and Greek at Basel.

Henle's spine: suprameatal spine. Jakob Henle (1809–1885) was Professor of Anatomy successively in Zürich, Heidelberg, and Gottingen.

Huschke, foramen of: gap in floor of developing tympanic ring. Emil Huschke (1797–1858) was Professor of Anatomy in Jena.

Jacobson's nerve: tympanic nerve (from glossopharyngeal). Ludwig Jacobson (1783–1843), an anatomist in Copenhagen, described the tympanic nerve and plexus.

Macewen's triangle: suprameatal triangle (a guide to the mastoid antrum). William Macewen (1848–1924) was Professor of Surgery in Glasgow.

Prussak's space: superior recess of the tympanic membrane (between flaccid part and neck of malleus). Alexander Prussak (1839–1894) was Professor of Otology in St. Petersburg.

Reissner's membrane: vestibular membrane (between scala vestibuli and cochlear duct). Ernst Reissner (1824–1878) was Professor of Anatomy in Dorpat and later in Breslau.

Rivinus, notch of: tympanic notch (in upper part of tympanic ring). The "foramen of Rivinus" (in upper part of tympanic membrane) is an artifact (Griffith). Augustus Rivinus (1652–1723) was Professor of Physiology in Leipzig. His father latinized the family name from Bachmann to Rivinus.

Scarpa's ganglion: vestibular ganglion of the vestibulocochlear nerve. Antonio Scarpa (1747?–1832) was Professor of Anatomy in Pavia.

Shrapnell's membrane: flaccid part of tympanic membrane. Henry Shrapnell (died 1834) was a military surgeon from Gloucestershire. The flaccid part had been noted by Rivinus more than a century earlier.

Tröltsch, space of: anterior and posterior recesses of the tympanic membrane. Anton Tröltsch (1829–1890) was an otologist in Würzburg.

REFERENCES

Bast, T. H., and Anson, B. J. A historical survey of the structure and function of the internal ear. Chapter 9 in *The Temporal Bone and the Ear.* Thomas, Springfield, Ill., 1949.

Dobson, J. *Anatomical Eponyms.* Livingstone, Edinburgh, second edition, 1962.

Griffith, A. The foramen of Rivinus—an artefact. J. Lar. Otol., *75*:607–613, 1961.

O'Malley, C. D., and Clarke, E. The discovery of the auditory ossicles. Bull. Hist. Med., *35*:419–441, 1961.

Wolff, D. A brief history of the early development of the anatomy of the ear. Laryngoscope, St Louis, *44*:1–28, 1934.

Wolff, D. Organ of Corti as we see it today, one hundred years after its discovery. Archs Otolar., *56*:588–609, 1952.

AUTHOR INDEX

Abbreviations ET, Glossary of Eponymous Terms at end of book, GR, General References at beginning of book

SUBJECT INDEX

The numerals are figure numbers and refer to either the illustrations themselves or the text facing them, or to both.

Items are usually listed under nouns rather than under descriptive adjectives For example, semicircular duct will be found under the heading "Duct," and external acoustic meatus under the heading "Meatus "